

**STUDIES ON THE ORIBATID MITES (ACARI: ORIBATEI)
ASSOCIATED WITH MANGROVE ECOSYSTEMS OF
NORTH KERALA**

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CERTIFICATE

This is to certify that this thesis entitled “Studies on the Oribatid mites (Acari: Oribatei) Associated with Mangrove Ecosystems of North Kerala” has been carried out by **Mr. Syamjith P.K**, a candidate for Doctor of Philosophy in Zoology under my supervision and guidance in the Acarology division of this department and that no part of this work has been presented before for any other degree.

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Dr. N. Ramani
(Supervising Guide)

DECLARATION

I, SYAMJITH, P.K, hereby declare that this thesis entitled “**Studies on the Oribatid Mites (Acari: Oribatei) Associated With Mangrove Ecosystems of North Kerala**” is an authentic record of the work carried out by me under the supervision and guidance of Dr. N. Ramani, Professor, Division of Acarology, Department of Zoology, University of Calicut and that no part of this has been published previously or submitted for the award of any degree, diploma, title or recognition before.

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SYAMJITH, P.K

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CHAPTER 1

GENERAL INTRODUCTION

Mangroves constitute one of the most productive ecosystems in tropical and sub tropical countries in the world. The term “mangrove” refers to an assemblage of tropical trees and shrubs that grows in the intertidal zone. These are the most productive, valuable salt tolerant coastal wetland ecosystems, distributed over the seaward fringes of many countries. As per the latest census of 2011, the mangrove vegetation in Indian coastline covers an area of 4,662 sq km. Over all 59% of the mangrove area lies along the East coast, 28% on the West coast and the remaining 13% in the Andaman Nicobar Islands (FSI, 2009, 2011). The Sunderban deltaic complex covers the largest single contiguous mangroves spread between India and Bangladesh. Among the South Indian states, Kerala had been blessed with good stretches of mangrove vegetation covering an area of about 700 sq kms in the past (Ramachandran and Mohanan, 1987). However, various natural cum anthropogenic activities resulted in a drastic decline in the mangrove ecosystem of Kerala and currently only mangrove vegetation is restricted to an area of 17 sq kms alone. The records of Kerala Forest Department in 2006 listed that about 88% of the mangroves in Kerala is under private property and rest is under the Kerala Forest Department. Majority of the mangrove

area of Kerala is found distributed in the Northern districts. The mangrove vegetations in North Kerala, especially in the districts of Malappuram, Kozhikode, Kannur and Kasaragod extend to areas of 12, 293, 755 and 79 hectares respectively.

The mangrove ecosystem is dominated by mangrove plants which contribute primarily as producers and interact with the neighbouring aquatic fauna, flora, physical and socio-economic factors of the coastal environment. The mangrove flora consists of both 'true' and 'associated' species, which are seen in restricted intertidal zones and in the vicinity of mangroves. The occurrence and distribution of different mangrove plants are not randomly scattered, but often occur in discrete and more or less monospecific zones. The intricate root system (pneumatophores, prop roots, and stilt roots) support numerous marine as well as freshwater benthic fauna in relation to the changing environment and also provide protection and shelter for coastal settlements against extreme weather conditions, such as storm winds and floods, as well as Tsunamis.

These diverse intertidal regions provide good shelter as well as breeding and feeding habits/ sites for both terrestrial and aquatic vertebrates and invertebrates. Mangrove plants produce large amount of litter, which would serve as sheltering accumulations of organic matter along with soil interstices. Especially the burrowing forms of intertidal invertebrates aerate

the soil and hence are considered as the integral parts for the structure, health and functioning of intertidal habitats. Being the active members of detritus food chains, some of these faunal elements play vital roles in triggering biodegradation and humification process, nutrient cycling and transfer of energy from lower to higher trophic levels.

Mites represent an abundant and highly diverse group among the soil invertebrates, the soil acari, especially the oribatid mites exhibit multiple roles, majority of which have been recognized under the beneficial category. They are ubiquitous in habit, enjoying diverse patterns of distribution in every nook and corner of the terrestrial, aquatic and aerial habitats available on earth. As of 2013, there are over 50,000 species of mites have been described to date and many taxonomists predict that the species richness of mites would be greater than that of insects. Thanks to the remarkable evolutionary plasticity and relatively small size of mites, which would have helped in their bewildering diversity in habits and habitats.

Among mites, the soil mites, particularly the oribatid mites or the cryptostigmatid mites represent the most numerically dominant, species rich group in almost all types of soils. As per the latest World Oribatid mite Catalogue compiled by Subias, 2004, updated (2015), the suborder oribatida comprises 10,695 species and subspecies (1,461 synonyms) recognized under 1,262 genera and subgenera (424 synonyms) and 164 families. Of these,

3,791 spp. are Palearctic; 1,114 spp. are Nearctic; 1,803 spp. are Ethiopic; 2,268 spp. are Oriental; 1,425 spp. are Australian; 97 spp. are Antarctic and 2,216 spp. are Neotropic in distribution (Plate-1, Fig.1). Around 11,000 species have been described so far and in temperate forest soils, a small area often harbours up to 150 species (Norton and Behan –Pelletier, 2009). These mites are characterized by incredible morphological and habitat diversity coupled with highly conserved biological features.

By virtue of their very vital role in litter fragmentation and associated soil humification process, these mites hasten the nutrient cycling and subsequent enhancement of soil fertility and productivity. In addition, oribatid mites play leading roles in bioindication of soil conditions including radioactive pollution, bioremediation, and biological control of pests, parasites and pathogens, detection of post mortem intervals and thereby catalyzing the advancement of forensic science and so on. The study of existing oribatid communities, greatly improves our knowledge on the ecology and biology of oribatid mites, which is of utmost importance in order to infer habitat changes. In soil ecosystems, especially in forest soils and litter accumulated areas, oribatid mites regulate decomposition and nutrient turn over by actively feeding on the litter substrates/microbial colonies, comminuting organic matter, feeding on microbes etc. which in turn would help in the mixing up of the microbial propagules with fresh resources in the fecal pellet, and often their transportation to new sites. The detritus like the

fallen leaves, decaying twigs, dead pneumatophores and prop roots function as the major feeding substrates for littoral invertebrates and microbes.

Oribatid mites inhabiting forest ecosystems are considered to have the origin of two types ie, littoral and arboreal. The littoral mangrove fauna always tend to submerge under daily, periodic inundation by the saline and sometimes fresh water. Therefore, they possess certain specialized characters specialized for the arboreal and littoral mode of life and develop some morphological modifications like tridactylous and monodactylous legs with toothed claw, reduced sensillus etc.

Relatively very few studies have been carried out presently, on the species diversity and functional status of oribatid mites harbouring the marine/ coastline, riverine and mangrove habitats, on a global level. Only limited number of the oribatid mites are known to exhibit a close association with the marine littoral habitats and to cite some examples are the members of the families viz. Ameronothridae, Selenoribatidae and Fortuyniidae of the superfamily Ameronothroidea. The mites restricted to this particular challenging environment by getting adapted themselves morphologically, physiologically and behaviorally are collectively termed as the “Intertidal oribatids”. Most of the intertidal oribatid mites are subjected to tidal currents, they become submerged partially or completely, and in such conditions, they possess certain morphological adaptations like the respiration accomplished

through more or less developed plastron mechanisms and the ability to withstand effects of seawater for prolonged periods. Among the truly intertidal oribatids, species like *Alismobates inexpectatus*, *Fortuynia atlantica* and *Carinozetes bermudensis* inhabit in the intertidal zones of tropical and subtropical coastal habitats and are known to possess well-developed plastron respiration mechanisms.

Various microhabitats are found exploited by the intertidal mites which include the rock crevices, barnacle shells, sand, intertidal debris, salt-marshes, supralittoral lichens, moss and some algal filaments and mangrove pneumatophores. Many of the marine associated mites are detritus feeders while some of them consume algae and fungi, and some others are carnivorous. Supralittoral species of mites have been classified (Pugh and King, 1988) into 3 categories viz. (a) maritime species, which include mites are limited to the seashore, especially supralittoral sometimes they guessing into the upper littoral zone (b) Non-maritime species which include mites which are habitually at the seashore and (c) Nomadic species which include mites which migrate freely from the littoral to the supralittoral zones.

The intertidal mites show their own particular modes of distribution in accordance with the various climatic conditions. Biological processes in soil ecosystems including the mangrove soils are more complex and soil-inhabiting mites take part in all vital processes by inoculating microbes

through grazing on microbial encrustations and introducing spores into fresh residues so that they can accelerate the decomposition process. As mangrove soils are detritus- based, they form ‘hotspots’ of microbial diversity. These microbes mediate decomposition and complex interactions between them and the detritus feeders like the mites culminate in the transformation of fresh and dead organic residues into either mineral nutrients or recalcitrant humic acids. Soil inhabiting animals perform both direct and indirect roles in this context by transporting the organic and inorganic materials within and between soil systems. The extend of oribatid feeding activity culminating in the release of nutrients which are locked in organic debris is very less explored and in mangrove ecosystems it still remains as an unexplored entity. Kerala being a land blessed with vast stretches of coastal areas and varied types of water bodies in the form of ponds, lakes, rivers, backwaters and swamps supplement diverse natural habitats for marine as well as terrestrial fauna. The soils of the intertidal (mangrove) areas of Kerala have not been explored so far for the elucidation of the faunal diversity of mites. Considering this lacuna, the present study was undertaken to explore the diversity of intertidal species of oribatid mites harbouring the mangrove ecosystems of North Kerala and also to trace the feeding and breeding habits of selected species. The study was also extended to gather information on the impact of oribatid mites in the release of nutrients in mangrove soils.

CHAPTER 2

REVIEW OF LITERATURE

Faunal diversity of mites, especially oribatid mites of mangrove ecosystems of the world in fact represents a very poorly explored area and in India, research works along this line are meager. Kerala being a land blessed with numerous wetland ecosystems supports rich and diverse faunal groups including mites. On a global level, our knowledge on the occurrence, distribution and systematic aspects of oribatid mites inhabiting different terrestrial ecosystems has been enriched by various authorities by supplementing data on the morphology, biology and other ecological parameters of these mites inhabiting in various terrestrial ecosystems at different time intervals. However, difficulties in the recovery of oribatid materials from extremely challenging ecological habitats like the mangrove ecosystems and wetlands, coastal, marine and intertidal systems etc. posed great threat in the progress in the taxonomic and biological studies of these mites and accordingly only very limited information is available in the present scenario. Hence, our knowledge on the faunal diversity and related biological aspects of mangrove dwelling oribatid mites is very much restricted on a global scale and in India, especially in South India practically very little is known on the diversity of these mites in mangrove ecosystems. Considering

the dearth of knowledge on this group of mites in general and that of mangrove ecosystems in particular and duly recognizing the very important roles they play in biodegradation, soil formation, stabilization and nutrient cycling leading to fertility enrichment etc. the present topic was selected for conducting detailed studies. Hence, in the present study an earnest effort was made to present the review in a concise form incorporating almost all available literature on oribatid mites inhabiting mangrove ecosystems of the world. Additionally, the present review also includes the details of earlier scientific explorations on oribatid mites inhabiting habitats like the seashores, islands, wetlands, coastal and intertidal area, salt- marshes etc. distributed throughout the world.

Information on the intertidal species of oribatid mites harbouring the rocky shores and estuaries of the West coast of Ireland was provided by Halbert (1915 & 1920) by conducting extensive surveys. A new genus viz. *Fortuynia* was erected by Van der Hammen (1960), based on the type species, *F. marina* collected from the intertidal areas of Netherlands, New Guinea. Strenzke (1961) described a new genus, *Selenoribates* with *S. foveiventris* as the type species from the Mediterranean Sea. Schuster (1963) erected a new oribatid mite genus viz. *Thalassozetes* based on the type species, *T. riparius* dwelling in an intertidal habitat at Adriatic Sea Coastal area, Croatia, Bulgaria.

A new genus and species of aquatic oribatid mite viz. *Hydronothrus crispus* was erected by Aoki (1964a) based on the specimens recovered from dead leaves of *Hibiscus tiliaceus* collected from the Island of Kauai, Japan. The same author (1964b) described another new genus viz. *Nesoribatula* with *N. pacifica* as the type species and 4 new species viz. *Scapheremaeus sinuosus*, *Multioppia wilsoni*, *Hypozetes laysanensis* and *Ceratozetes incurvus* from the Layson Island.

Grandjean (1966) described a new species, *Selenoribates mediterraneus* under the intertidal mite family Selenoribatidae from Paris, France. Schuster (1966) gave information on the distribution and habitat of marine littoral inhabiting oribatid mites. Karppinen (1966) investigated the Seashore inhabiting oribatid mite fauna of the Archipelago of Finland. Luxton (1967) provided the description of a new species of *Fortuynia* viz. *F. elamellata* inhabiting on the rocky shore of North Auckland.

Grandjean (1968) erected a new genus *Schusteria* based on type species *S. littorea* from an intertidal habitat. Hammer (1970) reported 8 known and 2 new species of oribatid mites from Easter Islands. The same author (1971) provided the description of 83 species of oribatids from the Fiji Islands, of which 8 genera and 43 species were new to science. She (1972) further described 60 species of oribatids from the Tahiti and Atoll Rangiroa which included 4 new genera, 36 new species and 5 new varieties. Fujikawa

(1972) conducted a survey on the oribatid mite fauna harbouring different vegetations along the Ishikari seashore. The result revealed the presence of 26 species under 25 genera of which, the largest number of individuals was obtained from the vicinity of plant species like *Sasa paniculata* and *Quercus dentata*.

Description of 13 new genera and 57 species of oribatids collected from the Tongatapu and Eua, the Tonga Islands and Upolu was made by Hammer (1973). Data on the distribution and ecology of oribatid mites belonging to the family Ameronothridae harbouring from the terrestrial, limnic and marine habitats of Europe and North America were provided by Schulte *et al.* (1975).

Schuster (1977) enriched our knowledge on the Thalassobiontic oribatid mite family, Selenoribatidae. He further (1979) listed a number of soil mites recovered from the marine environments, especially from the supralittoral as well as in the intertidal area. An extensive survey conducted by Hammer (1979) on the oribatid mites of Java enabled to erect 58 genera and 165 species, of which 10 genera and 103 species were new to science.

Talker *et al.* (1981) studied the oribatid mite fauna of intertidal habitats of the seacoasts of Cebu. They added taxonomic information on the families, Selenoribatidae and Fortuyniidae with the help of SEM images along with description of other acarines.

Aoki (1982a) erected 9 new species and 2 subspecies of oribatid mites from the Southern Islands of Japan. The same author (1982b) reported 28 species of oribatid mites, including two interesting species, *Hoplophthiracarus hamatus* and *Eremaeozetes octomaculatus* from the Minami-Iwojima, Islands of Japan. He (1984) provided detailed descriptions along with new records of oribatid mites from the Amami-Oshima Island, South west Japan. Sengbusch and Sengbusch (1984) prepared a preliminary checklist of oribatid mites collected from the Island of Kahoolawe, Hawaiian oribatid species that comprised the report of 11 species under 10 families, including 2 new and 2 undescribed species. Luxton (1984) identified a novel species of oribatid mite, *Halozetes bathamae* under the family Podacaridae collected from the marine littoral zone of New Zealand.

Søchting and Gjelstrup (1985) reported a number of oribatid mite species from the lichens associated with the rocky seashore's of North Bornholm. Luxton (1986) added an account on a new species, *F. maculata* collected from the marine littorals of Silver Islands of Kenya. Data on several species of oribatid mites inhabiting the coastal zones of Antarctica were provided by Niedbala (1986) and he also erected a new species, *H. impeditus* from the King George Island. Aoki (1987) described three new species of oribatid mites belonging to a new genus, *Yoronoribates* from the Yoron Island of South Japan. Ito *et al.* (1987) conducted surveys in different vegetations to explore the oribatid mite fauna of Ishigaki Island, Okinawa, Japan.

Our knowledge on the Indian oribatid mites was enriched by Sanyal and Bhaduri (1988) who reported a total number of 262 species under 132 genera and 57 families distributed over 15 States. Altogether 5 genera, 103 species, 11 subspecies and 1 variety were described as new to science. Pugh (1988) provided a succinct review on the shore- inhabiting Acari of the Isles of Scilly and South- West Peninsula. Piantelli *et al.* (1990) studied the equilibrium theory of mollusks and oribatid mites of the Aeolian and Tuscan Archipelagos.

Luxton (1990a, b) made a summary on the local distribution pattern of some marine littoral oribatid mites of the New Zealand region. In another paper, the same author (1990c) recorded and enlisted 44 species of oribatid mites from the Isles of Scilly, which contained the illustrations and descriptions of 2 species viz. *Ramusella assimilis* and *Passalozetes bidactylus*, reported for the first time from the British Islands. The same author (1990d) listed 15 species of oribatids from the Holy Island.

Schatz (1991) prepared a catalogue to the known oribatid mites of the Galapagos Islands in the Pacific Ocean. Morell and Subias (1991) listed the oribatid mites collected from many Islands of the archipelago of the Azores of which, 10 were reported as new to science. Luxton (1992) described 4 new genera and 7 new species of oribatid mites from the marine littoral of Hong Kong. A key to the tropical and subtropical littoral oribatid fauna was also

provided. He (1993) erected a new species under the genus *Dometorina* viz. *D.rostrata*, infesting the dead leaves of a mangrove plant, *Avicennia marina* from Hong Kong. A key to the known species of the genus *Dometorina* was also given. Schatz (1994) reported 12 species of Lohmaniid mites from the Islands of Galapagos, Cocos and Central America. Baratti and Bernini (1994) described a new species of Carabodid mite viz. *Odontocepheus oglasae* from Montecristo Island of the Tuscan Archipelago. Mahunka (1994) identified a new genus and species of oribatid mite under the family Microzetidae viz. *Comorozetes atavisticus* collected from the soil samples of the Comoro Islands of Africa. The new genus was distinguished by the possession of certain very peculiar characters including 4 pairs of anal setae and shape of the robust setae of palp tarsus.

A new genus viz. *Cordylobates* was erected by Luxton (1995) from the Ascension Island with *C. fragilis* as the type species. Stary (1995) reported 12 species of oribatid mites, including 2 new species viz. *Furcobates levissmithi* and *Oribatella blocki* from Beauchêne, the most isolated Islands Falklands, situated in the South Atlantic Ocean. Norton *et al.* (1996) studied and redescribed the aquatic oribatid mite genus, *Mucronothrus* from California, Oregon and Montana, based on the characters of adults and immatures. Two species were discussed of which, one was new to science. Niedbala and Schatz (1996) reported 37 new species of euptyctime oribatid mites of the families Phthiracaridae, Euphthiracaridae, Oribotritiidae and Steganacaridae

from the Islands of Galapagos, Cocos and Central America. Marshall and Pugh (1996) recorded seven families of oribatid mites from the inland areas of continental Antarctica.

Starý *et al.* (1997) reported 3449 species of oribatid mites from the sub-Antarctic Heard Island. Yamamoto and Aoki (1997) described a new species, *Malaconothrus iriomotensis* from very wet moss habitats, the foot of Kanpire Waterfall in Irimote Island, Southwest Japan. The new species was very similar to *M. yamamotoi* and *M. kiiensis* and it differed from the known species by having smooth and thin rostral setae, 4 pairs of smooth notogastral setae (e_2 , h_1 , h_2 and ps_2), possession of some inner spots on lamellae and area between paired setae d_1 and in the short length of genital and adanal setae. Williams and Williams (1998) collected and reported 20 species of oribatid mites from the fresh water and brackish habitats of Bermuda Islands.

Schatz (1998) made a review on the ecology, faunistics and speciation pattern of oribatid mites inhabiting the Galapagos Islands. While studying the distribution pattern and biogeography of some oribatid mites inhabiting the Islands of Antarctica, sub-Antarctica and nearby land areas, Starý and Block (1998) observed the numerical dominance of members of the families Oppiidae and Ameronothridae. A catalogue to the oribatid mites recovered from the Kashima Islands of Tanabe Bay, Japan was prepared by Yamamoto (1998). Marshall *et al.* (1999) described 23 species of oribatid mites collected

from the sub-Antarctic Marion and Prince Edward Islands, of which 2 species belonging to the families Brachychthonidae and Ceratozetidae were new records.

Mercer *et al.* (2000) reported 6 species of oribatid mites from the rocky shores of Marion Island. A novel species of *Eremaeozetes* viz. *E. sabinae* was described by Schatz (2000) from the Hawaiian Islands. An account on the global distribution pattern of non- halacarid marine- intertidal mites with respect to their origin in marine habitats, including 45 species of oribatid mites belonging to 13 genera and 4 families was provided by Proches and Marshall (2001). The occurrence of the members of the oribatid family Oribatulidae in the mangrove pneumatophores collected from the KwaZulu-Natal, South Africa was reported by Proches *et al.* (2001). While reviewing the progress made in the hundred years of acarology in the Hawaiian Islands, Swift (2001) and Swift and Goff (2001) reported 43 species of oribatids harbouring different habitats of natural reserves on the Kauai's Island.

A taxonomic survey carried out on the oribatid mites of the Ogasawara Islands of Japan by Aoki (2002) enabled to describe 2 new species viz. *Diplobodes karubei* and *Xylobates rotundus*. Three new species under the genus *Fortuynia* belonging to the superfamily Ameronothroidea were erected by Marshall and Pugh (2002) from the rocky shores and mangrove litters of Southern Africa. A report on the biodiversity and biogeographical distribution

pattern of intertidal acarines of the Southern Africa was made by Proches and Marshall (2002a). The same authors further (2002b) investigated the abundance of acarines in the intertidal mangrove pneumatophores. Niedbala and Niemi (2002) documented the morphological features of some Phthiracaroid mites inhabiting the Pacific Islands, based on Scanning Electron Microscopy. Taxonomic studies carried out by Niedbala (2002) on the ptyctimous mites of the Bermuda Islands yielded 18 species, of which 5 species were new records.

The dominance of oribatid mites in the mudflat baring edges of the mangrove plant, *A. marina* in West Australia was reported by Bartsch (2003). The association of several species of oribatid mites with the mangrove forests of the smaller Okinawa Island of Japan was studied by Karasawa and Hijii (2004a) with respect to their morphological changes. The same authors (2004 b) conducted studies on the microhabitat diversity of some oribatid mites inhabiting the mangrove forest of Ryukyu forest in Japan, and observed significant species composition under the barks of knee-root and trunks of *Bruguiera gymnorrhiza*.

Studies by making a preliminary collection of oribatid mites from the Samar Island natural park, Philippines enabled Corpuz-Raros and Gruezo (2005) to report 123 species under 93 genera, 40 families and 4 suborders. Based on washing and direct sampling methods, Karasawa and Hijii (2005)

identified 1,005 individuals representing 23 species of oribatids from the leaves and branches of mangrove plants, from the Okinawa Island, the Ryukyu archipelago of southwest Japan. Moraza and Pena (2005) conducted a faunistic survey of oribatid mites and recorded 150 species representing 56 families, from selected habitats of Canary Islands, Spain. Two new species of *Schusteria* viz. *S. nagisa* and *S. saxea* and one new species of *Rhizophobates* viz. *R. shimojanai* were collected and described by Karasawa and Aoki (2005) from the marine littorals of the Ryukyu Archipelago, South Western Japan. The authors transferred 2 African species of the genus *Schusteria* viz. *S. melanomerus* and *S. ugraseni* to the newly described genus.

Niedbala *et al.* (2006) described 24 species of ptyctimous mites from Samar Islands of the Philippines. Seniczak and Seniczak (2006) provided information on 12 species of oribatid mites collected from mosses, lichens and litter samples of Rhodes Islands of Greece and recorded the abundance of members of genera *Pilogalumna*, *Metabelba* and *Haplochthonius*. Information on the occurrence of 36 species of oribatid mites belonging to 28 genera and 21 families inhabiting the Sundarban delta of West Bengal, India was provided by Sanyal (2006).

Karasawa and Behan (2007) described a new species of oribatid mite belonging to the monotypic genus, *Symbioribates*, viz. *S. aokii* collected from the canopy habitats of Ryukyu Islands, Southwestern Japan. The authors

supplemented drawings and SEM photographs of the species along with the descriptions. Majka *et al.* (2007) presented 4 oribatid families viz. Nothridae, Camisiidae, Ceratozetidae and Hydrozetidae, as new records for the Sable Island of Canada.

Krisper and Schuster (2008) described a new species, *F. atlantica* from the rocky coasts of Bermuda Islands. Scanning Electron microscopy was employed to illustrate the intraspecific variation of the various morphological characters. Karasawa and Hijii (2008) reported 16,325 oribatid mites representing 81 morphospecies from the same habitat with respect to their morphological and life history traits.

While conducting a survey on the oribatid mite species inhabiting 11 different habitats including 4 forest types, 2 bogs, ant hills, decaying wood, moist & dry meadow and seashore in Finland, Penttinen *et al.* (2008) reported 165 species of oribatids of which, 17 were new reports from Finland and 52 were confined to the seashore and 12 were distributed in all the habitats mentioned above.

Weigmann (2008) described a new species, *Peloptulus sacculiferus* of the family Phenopelopidae from the coastal habitats of Minho River, of the Lagoon of Aveiro, Southwestern Algarve, Portugal. Further, he redescribed a related species viz. *P. reticulatus* inhabiting at the border of the salt marshes

in the Lagoon of Faro, Southern Portugal and declared *P.trinacriae* as a junior synonym of *P. reticulatus*.

Winchester *et al.* (2008) provided information on 33 species representing 26 genera and 19 families of oribatid mites inhabiting on the canopy of Montane *Abies amabilis* and *Tsuga heterophylla* trees on Vancour Island of British Columbia. Bayartogtokh *et al.* (2009) conducted a taxonomic study on the marine littoral mites of the family Fortuyniidae collected from Taiwan and India. The authors also described 2 new species viz. *F.taiwanica* and *F. Arabica* along with a key to the world's known species and subspecies of different genera and data on their distribution. Monson (2009) erected a new species under the genus *Carabodes* viz. *C. scaber* collected from varying habitats of the British Isles.

An investigation on the geographical diversity of oribatid and mesostigmatid mites of Greenland was carried out by Makarova and Böcher (2009) and they listed 109 identified oribatid species. The authors found that 70% of the oribatids were widely distributed (Holarctic and wider), 31% were cosmopolitan or semi cosmopolitan and 5% were conditionally endemic in distribution.

Weigmann (2009a) erected a new halophilous oribatid species, *Punctoribates aveiroensis* from the salt meadows at an upper tidal level in the Lagoon of Aveiro, Portugal. Redescription of 2 species under the known

genus, *Zachvatkinibates* based on the species *Z. quadrivertex* and *Z. eoeryi* recovered from the marine salt-marsh of the same region was also presented by the author. The same author (2009b) erected 2 new species of the families, Scutoverticidae viz. *Scutovertex mikoi* and *Micropirnodus longissimus* a new genus under Scheloribatidae from the coastal habitats of Portugal. He also made a discussion on the new taxonomic position of the genus *Euscheloribates* as a subgenus of *Scheloribates*.

Pfingstl *et al.* (2009) described 2 new epilittoral species, *S. arenocolus* and *S. pilosetosus* from the sandy shores of the European coasts. Based on morphometric and principal component analysis, these 2 species could be well separated from *S. minutus* and they confirmed distinctly shorter cusps and notogastral setae in *S. arenocolus*.

Bayartogtokh and Chatterjee (2010) proposed a newly revised diagnosis for the genus, *Thalassozetes* and described a new species *T. tenuisetosus* from the marine coastal areas of Western India. In addition to that supplementary description on *Peloribates kaszabi*, *Scheloribates latipes* and *Pergalumna* cf. *foveolata* was also given. Behan-Pelletier (2010) gave information on the species diversity of oribatid mites in the ecoregions of the Atlantic maritime Ecozone. She recorded 196 species belonging to 118 genera and 58 families. Through a survey on the soil mites inhabiting sand dune habitat of West Coasts of Ireland and Scotland, Arroyo and Bolger (2010)

listed several species of oribatid mites. De la Riva-Caballero *et al.* (2010) studied the assemblages, transportation and deposition of Paleolimnic oribatid mites in lake sediments and plant remains of the tree line in Western Norway. Norton and Corpuz-Raros (2010) described a new species of oribatid mite of the family Hypochthoniidae viz. *Nothrolohmannia samarensis* from the Samar Island of Philippines. Weigmann (2010) erected 4 new species of oribatids viz. *S. littoralis*, *S. ibericus*, *Haplozetes differens* and *Coronoquadroppia guttata* from the bush-land in the estuary region of the Ribiera de Aljezur, Portugal.

Aoki and Shimano (2011) surveyed the oribatid mite fauna of Daikoku-Jima Island, Northern Japan and recorded 34 families, 45 genera and 56 species. Bayartogtokh *et al.* (2011) conducted studies on the diversity and distribution of oribatid mites from the Svalbard Island in the Arctic Ocean. The authors provided redescriptions for 3 known species, *Camisia dictyna*, *Ceratoppia sphaerica* and *Diapterobates notatus* with supplementary descriptions and illustrations. Mahunka (2011) surveyed the oribatid fauna of Madagascar and described 6 new species, Shtanchaeva *et al.* (2011) collected 36 species of oribatid mites from 17 different habitats of Coastline and Islands of Caspian Ocean and erected a new species *Oribatula (Zygoribatula) caspica* from reed bed meadows.

Corpuz-Raros and Gruèzo (2011) described 5 new species of oribatid mites along with other soil- inhabiting mites collected from Luzon and Mindanao Islands, Philippines. Kagainis and Eitminavičiūtė (2011) reviewed and published the results of 46 years old records of unpublished data of Lithuanian expedition made along the coast of Baltic Sea in the territory of Latvia. The results of the expedition enabled to recover 62 species and 25 morphospecies of oribatid mites, of which 10 were new to science.

Niedbala (2011) described a new species of the genus *Arphthycarus*, viz. *A. andamanensis* from the Andaman Islands. The extensive survey carried out by Wisdom *et al.* (2011) helped to gather information on the occurrence of 43 species belonging to 22 families from the Irish Peat lands. Weigmann (2011) reported, described and redescribed the oribatids of the genera *Xenillus*, *Oribatella*, *Galumna*, *Eupelops* and *Lucoppia* from the salt marsh zones (rocky habitat) of Portugal. Two species viz. *X. halophilus* and *G. paragibbula* were new to science.

Colloff (2012) described 10 new species under the Eremaeozetidae from the Southwestern Pacific region, Australia. He also erected 4 new species under the genus *Rostrozetes* viz. *R. koghisensis*, *R. mirabilis*, *R. novaecaledoniae* and *R. fernandezi*, and he presented a key to the genus. A concise review on the oribatid mites transported by birds to the Polar Islands was given by Lebedeva (2012). Schatz and Schuster (2012) recorded and

described 9 species of oribatid mites under the family Lohmanniidae from the Main Island of Bermuda as a first report.

Pfingstl and Schuster (2012a) redefined the family Fortuyniidae based on the adult and juvenile morphology and life history of a new species of littoral mite, *Alismobates inexpectatus* collected from the Atlantic Ocean as the first record. The same authors (2012b) erected a new genus *Carinozetes* with *C. trifoveatus* as the type species from the green algae and pneumatophores of the upper intertidal area of Bermuda Islands. Ermilov *et al.* (2013) provided a checklist of oribatid mite fauna from riverine environments of six Oceania Islands (Australian region) and made a detailed description of a new species of *Fortuynia* viz. *F.smiti*.

An account on the oribatid mites collected after a tidal wave (Tsunami) from the seashore of Tohoku, Japan, was provided by Nakamura *et al.* (2013) which comprised of the descriptions of 9 species including 6 new species. Pfingstl (2013a) conducted studies on the diversity of a small family of intertidal oribatid mites viz. Selenoribatidae. He described 3 species viz. *S. quasimodo*, *S.satanicus* and *S.elegans* as new to science from the Archipelago of Bermuda.

Penttinen and Hämäläinen (2013) conducted studies on the distribution and habitat of a small population of an endemic species, *Austrotritia finlandica* from Finland. Altogether 400 soil samples from

several Islands were investigated, the species was recorded in 16 samples on 13 Islands. Altogether, 64 specimens were collected.

Julie *et al.* (2013) conducted studies on the diversity of oribatid mites inhabiting mangrove ecosystems of the Calicut district of North Kerala, India and the results of their studies revealed the presence of 17 species belonging to 15 genera and 14 families. Seniczak *et al.* (2013) investigated the oribatid fauna inhabiting at the edges of bog lakes and pools in Brodnica Lakeland and Orawa- Norvy Targ basin, Poland. Weigmann (2013) provided a detailed systematic list of the oribatid species collected from the coastal areas of Portugal.

Pfingstl *et al.* (2014) erected a new species under the genus *Carinozetes* viz. *C. mangrovi* from the intertidal algae collected from the Islands of Bermuda and Barbados. García-Gómez *et al.* (2014) conducted studies on the mesofaunal arthropod diversity of mangrove litter from the Cozumel Island of Mexico and the most abundant species recorded were oribatid mites (61.8%) followed by springtails (14%). Iseki and Karasawa (2014) newly recorded the presence of the genus, *Maculobates* based on the recovery of the specimens of *M. bruneiensis* from the mangrove ecosystems of Ryukyu Islands, Japan. Molecular phylogenetic analysis of the specimen was also carried out based on 18S rRNA and the results of which supported the monophyly of Oripodoidea.

While investigating the oribatid fauna of Priazovsky National Wildlife Sanctuary including Kuban Delta, a Ramsar convention wetland, Zaitsev and Pystina (2014) recorded 40 species belonging to 22 families. The authors also established the prevalence of surface – dwelling oribatid mites in sandy coasts and salt marshes in comparison with other oribatid mites from liman – reed beds and rice paddy fields. A new subgenus and 2 new species of Cosmochthoniid mites collected from the olive grove in the South of the Iberian Peninsula were described by Jorin (2014). Pfingstl (2015a) described 4 new species of intertidal oribatid mites under the genus *Selenoribates* viz. *S. asmodaeus*, *S. arotroventer*, *S. nicus* and *S. divergens* from the coastal regions of Indo- Pacific and Red Sea. He gave information on the morphological diversity in *Selenoribates* based on newly described species. Identification key and global distribution map to all species was also provided. The same author (2015b) described 3 new species, 2 under the genus *Fortuynia* viz. *F. longiseta* and *F. maledivensis* and one species under *Alismobates* viz. *A. pseudoreticulatus* from the littoral environments of Maldives and Singapore. A key to the adult species was also given.

I. Mangrove Ecosystems Sampled:

Being the most numerically dominant mesofaunal elements of the edaphic ecosystem, oribatid mites exhibit diverse types of interaction with their natural environment and thus occupy almost all available ecosystems in the world. Despite their well-known habitats like the forestlands and other litter-accumulated areas, mangrove soils containing organically derived substrata comprising the litter, pneumatophores and remnants of true mangrove plants or mangrove associates were selected as the sampling sites during the present study for the recovery of oribatid mites. Being highly challenging habitat with frequent exposure to tidal currents, mangrove ecosystems generally support highly specialized floral and faunal elements and this is applicable to the oribatid mite fauna also, necessitating the adoption of special collection procedures with utmost care. In the present study, a total of 15 sampling sites from various mangrove ecosystems distributed over 4 districts of North Kerala viz. Malappuram (**MPM**), Kozhikode (**KKD**), Kannur (**KNR**) and Kasaragod (**KSD**) (Table-1; Plate-2, Figs.1-5) were screened for the collection of oribatid mites. Regular/intermittent sampling was carried out from the study sites mentioned below to

recover most important and locally available oribatid mite fauna. All the sites sampled were found to support diverse vegetation composed of characteristic true as well as associate mangrove species (Plates,3-4,Figs.1-8; Plate-5, Figs.1-9).

II. Sampling Localities Screened:

A. MALAPPURAM DISTRICT (Sites1&2; Plate-6, Figs. 1&2)

Malappuram district lies on the'' top of hills'' and bounded North by Wayanad and Kozhikode districts and Southeast and Southwest by Palakkad and Thrissur districts respectively, and enriched with well-known rivers viz. the Chaliyar, Kadalundi and Bharathappuzha. Two sampling sites, viz. Brahmasampadam (**BRSPM**) and Olipramkadavu (**OPKDV**) were selected from the Malappuram district for collection of mangrove soil/litter/bark/pneumatophores/leaves/twigs etc. for the extraction of oribatid mites. The mangrove vegetation of the area mainly comprises *A. marina*, *A. officinalis* and *Acanthus ilicifolius*. (Table.3).

1. Brahmasampadam (**BRSPM**) (Plate- 6, Fig.1)

This site supports small patches of true and associate mangrove vegetation, located 4 kilometers away from the Calicut University Campus and 5 kilometers away from the seashore with coordinates, 11° 7'35.36"N and 5°52'8.46"E respectively. From this site, narrow water channels run up to

Olippuzha (Kadalundi River). The major vegetation includes *A. marina*, *A. officinalis* and *Acrostichum areum* (Table.3)

2. Olipramkadavu (OPKDV) (Plate -6, Fig.2)

This site is a small sandy area located at 11° 7'41.40"N 75°51'50.72"E in the banks of the river Olippuzha. The vegetation is dominated by true mangrove species, *A.ilicifolius*, *A.marina*, *Pongamia pinnata* and *A.areum*. (Table.3)

B. KOZHIKODE DISTRICT: (Sites 3-7; Plate -6, Figs. 3-7a)

There are 5 study sites from this district were Kadalundi- Vallikkunnu community reserve mangrove (KVCR-I& II) Kottakkadavu (KTKDV), Mankavu (MNKV) and Kallai (KLAI).

Kadalundi-Vallikkunnu Community Reserve Mangrove (KVCR-I&II) (Plate-6, Figs.3&4)

This was the major study site located at 11°07'33.76" N. and 75°49'49.40" E. This is the State's first community reserve in India, declared in 2007. It is a home and breeding site for various shoreline migratory birds, fishes and crustaceans. It is distributed across an area of 1.5 km² at the estuary of the Kadalundi River, Kozhikode and Malappuram districts of North Kerala.

3. Kadalundi-Vallikkunnu Community Reserve Mangrove –I (KVCR-I)

(Plate-6, Fig.3)

KVCR-I is a mangrove area situated at (11° 7'37.51"N and 75°49'54.64"E), at the mouth of the Kadalundi River, below the Railway Bridge. This site is composed of sandy mudflats with relatively good patches of true and associate mangroves and constantly exposed to regular tidal flooding. The flora includes the mangrove species viz. *A.marina*, *A.officinalis*, *R. mucronata*, *Derris trifoliata*, *Clerodendrum inerme*, *P. pinnata*, *Excoecaria agallocha*, *Mariscus javanicus* and *Wedelia chinensis* etc. (Table.3)

4. Kadalundi-Vallikkunnu Community Reserve Mangrove –II (KVCR-II) (Plate-6, Fig.4)

KVCR-II is a site adjacent to the terrestrial area and just away from the coastline habitat and is located at (11° 7'54.89"N and 75°49'44.55"E). This site is mainly formed by both sandy and loamy soils. Either sides of this site are bordered by true mangrove species like, *A. ilicifolius* and *A. officinalis*. This area is partially flooded by the seawater during high tidal waves. The mangrove vegetations are *A.marina*, *A.officinalis*, *M.javanicus* (Table.3)

5. Kottakkadavu (KTKDV) (Plate -6, Fig.5)

This site is bordered by the Kozhikode and Malappuram districts and is located at 11°8'15.99"N and 75°50'28.26"E. The site is characterized by mangrove vegetations viz. *A.officinalis*, *E. agallocha* are growing along the banks of the Kadalundi River. (Table.3)

6. Kallai (KLAI) (Plate- 6, Fig.6)

Kallai is a well-known timber-trading place in south India. The study site selected in this area is located on the bank of the Kallai River at 11°14'16.72"N and 75°47'14.12"E. The vegetation of the site mainly comprises mangrove trees like *A. marina* and *A.officinalis*. (Table.3)

7. Mankavu (MNKV) (Plate -6, Figs.7& 7a)

This site was located at 11°14'7.69"N and 75°48'13.52"E on the banks of the Mampuzha River, some 5 Km away from the Kozhikode city. This site was dominated by true mangrove species like *A.ilicifolius* and *A.officinalis* and a mangrove associate *A. marina*, *A. ilicifolius* and *Ipomea- pes- caprae*, (Table.3)

C. KANNUR DISTRICT: (Sites 8-15; Plate- 7, Figs. 1-8)

Kannur is popularly known as “the land of looms and lore’s”. The district lies between latitudes 11°40'12.48"N and longitudes 74°52'76.07"E. Kannur is geographically divided into highland, midland and lowland regions

where the lowland is comprised of a narrow stretch containing rivers, deltas and coastal regions. Six collection sites as listed below were considered for the sampling purpose during the present study.

8. Thalassery (TLSRY) (Plate -7, Fig.1)

The collection site in Thalassery is very near to the Thalassery railway station and it lies at 11°45'18.12"N and 75°29'30.58"E in the Kannur district. This area embraces a number of small patches of mangroves scattered over the water logged area and is with mixed mangrove vegetation. The most dominant species are *A. marina*, *R. mucronata* and *D. trifoliata*. (Table.3)

9. Koduvalli (KDVLV) (Plate -7, Fig.2)

This is a small site in Kannur Dt. and is located on the banks of the Kuyyali River, at 11°45'59.30"N and 75°28'42.06"E, supporting mangrove plants viz. *A.marina*, *A.ilicifolius* and *R. mucronata* (Table.3)

10. Valapattanam River Bank (VLMRVR) (Plate- 7, Fig.3)

This site is situated in the Kannur Dt. at the banks of the Valapattanam River at 11°56'3.92"N and 75°21'4.73"E. Densely growing mangroves are found along either sides of the river, giving scenic beauty to the site. The materials mainly collected from this site include the mangrove litter, pneumatophores and decayed twigs. This site characterized by the most

dominant mangrove species viz. *A.marina*, *A.ilicifolius*, *A.officinalis* and *Aegiceras corniculatum* (Table.3)

11. Dharmadam (DRMDM) (Plate -7, Fig.4)

The selected sampling site at Dharmadam is a mud flat situated on the Anjarakkandi River at 11°46'51.88"N and 75°27'42.69"E, in the Kannur Dt. It is a mangrove growing area comprising of *A.marina*, *A.ilicifolius* and *R.apiculata*. (Table.3)

12 & 13. Ezhome (EZHM) -I & II (Plate- 7, Figs. 5&6)

It is a small village in Kannur district and is known for the saline-tolerant Kaipad rice cultivation in Kerala. Two sampling sites selected in this locality (Ezhome I & II) are characterized by the presence of almost all types of mangrove vegetation including *A.marina*, *A.ilicifolius*, *A.officinalis*, *M.javanicus* *A.corniculatum*, *E. agallocha* etc. (Table.3)

14. Pazhayangadi (PNGDY) (Plate -7, Fig.7)

It is a small township located approximately 22 kilometers away from the Kannur town and lies at 12° 1'36.90"N and 75°16'24.05"E. One side of the sampling site in this locality is bordered by the Pazhayangadi River in which small patches of mangroves are found distributed in small islands. This site is dominated by mangrove vegetation comprising of *A. ilicifolius* and *E. agallocha*. (Table.3)

D. KASARAGOD DISTRICT (Site15; Plate- 7, Fig. 8)

Kasaragod, the northernmost part of Kerala covers an area of 1,992km² and lies north of Kannur district. It is famous as “land of gods”, awesome hills, rivers and beautiful beaches and well known for the preservation of the largest fort in the state. Only one site as listed below has been screened in this district for collection of oribatid mites.

15. Nileswaram (NLSRM) (Plate- 7, Fig.8)

It forms a small area in the Kasaragod District and it lies at 12°15'58.03"N and 75° 7'13.61"E. The sampling site in this area is located 2kms away from the Nileswaram railway station and the vegetation includes *A.ilicifolius* *A.officinalis* and *A.marina* etc. (Table.3)

III. Collection of Oribatid Mites

1. Sampling (Plate- 8, Figs. 1-8)

Collection of samples of soil/ litter/ /pneumatophores and other mangrove debris from the above-mentioned sites was carried out for a period of 5 years (2010 – 2015). Sample collection was mainly performed during the early hours of morning and late evenings, depending up on the prevalence of tidal currents. In the case of undisturbed areas of the selected mangrove habitats, soil samples were collected from the soil surface under the different vegetation types, using a shovel. Samples were also retrieved from the

mangrove litter, decayed twigs, decomposing bark of flooded trunks, pneumatophores etc. of true and associate mangrove plants. The collected samples were transferred into polythene bags and labeled with detailed field data like the topographic features of the site, vegetational characteristics, soil texture etc. Individual samples bearing field labels were brought to the laboratory for extraction of mites.

2. Extraction of samples

The extraction method used in the present study is based on Berlese's (1905) funnel extraction principle modified by Tullgren (1918). Based on their negatively phototactic habit, samples were subjected to extraction under the Open Brass Funnel Apparatus (Haq and Ramani, 2002) (Plate-9, Figs. 1-3) until the samples were completely dried. (Extraction time was found varied depending on the moisture content of the sample).

(i). Open Brass Funnel Apparatus (Plate-9, Figs.1-3)

The frame of this rectangular unit (183cm x 46cm x 170cm) is made up of steel and resting on four legs. The bottom and top of the unit are covered by steel sheets. Two rows of wooden planks with 12-13 holes respectively, are provided with funnels and sample container on each plank. At the tail end of each funnel, a glass/plastic collection vial (6cm X 2cm) is placed which in turn is kept on a spring mounted over a brass block to ensure

firm attachment between the funnel end and the collection vial. The Open Brass funnel apparatus contains 25 sampling units.

Each sampling unit is composed of 4 parts:

(A) Heat source (B) Sample container and Resting Shield-

(C) Collection vial - & (D) A metal spring with base-

A. Heat source:

In the present study, electric bulbs of 40/60/100 Watts were used as the heat source, depending up on the nature and moisture contents of samples collected. The distance between the bulb above and the sample below was normally kept 12 cm, but it was increased or reduced by lifting or lowering the wooden planks with the help of screws attached at the corners, as per requirement.

B. Sample container and Resting Shield

Each sample container is made of brass and was circular with a height of 10 cm and diameter of 15 cm. A fine wire mesh of 0.8 mm size and 15 cm in diameter is attached to the container, which served as the bottom of the sample container. Larger animals could escape through the gap between the base and lower rim of the sample container. Below the sample container, a round resting brass made shield of 17 cm diameter and larger mesh size of 0.5 cm is kept which served as the resting shield. A conical brass funnel

measuring 22 cm in length and 15 cm in diameter at the mouth end with steep and smooth inner sides supports the resting shield and the sample container. The sample container is held well in position on the resting shield and the latter is placed above the holes in the wooden plank because of the raised edges of the funnel. The tail region of the funnel has a diameter of 2 cm.

(C) Collection vial

A glass or plastic specimen tube of 6 cm x 2.5 cm was used as the collection vial. The mites extracted out of the collected samples were collected either in the preserved condition or as alive in to 70% alcohol /distilled water taken in the collection vial. It was placed beneath the tail end of the funnel with the help of a spring mounted on a brass square block.

(D) Metal spring with base

This helps to hold the vial appropriately below the tail end of the funnel in close proximity. The soil mites escaping from the collected soil/litter would descend through the filter in to the 70% alcohol/ water kept in the collection vial, for subsequent taxonomic/biological studies.

(ii). Direct Sampling Method (Plate -9; Fig. 4)

Live mites were collected from epiphytic algal cushions, dead plant twigs, decaying bark and pneumatophores of the true mangrove plants and

mangrove associates through direct examination under a stereozoom research microscope.

(iii) Washing Method (Plate -9; Figs. 5-8)

The washing method adopted in the present study was based on the technique of Karasawa and Hijii (2005) with slight modification. Oribatid mites colonizing the arboreal habitats like leaves and small twigs of true and associate mangroves were collected and immersing these substrates in water mixed with approximately 2 teaspoons of detergent (Surf Excel, Hindustan Uniliver Ltd.; Plate-9, Fig. 5) in a bucket (**ca. 5 L**). The bucket was then covered with a cloth/white paper to prevent invasion by other animals and kept overnight (10 to 12 hrs) in indoor condition (Plate-9, Fig.6). Leaves and branches were then washed manually in the bucket spiny plant species like *A. ilicifolius* and *C. crista* were washed with extra care and the solution was filtered through a nylon mesh of around 100-µm mesh size (Plate-9, Figs.7&8). Added 3-5 ml of ethanol to the solution to remove the excess soap bubbles. The oribatid mites thus recovered from the sediments through the nylon mesh, were segregated under a stereozoom microscope.

3. Separation of Mites

The mites extracted under the Open brass funnel apparatus in to the collection vials were transferred in to a watch glass and thoroughly examined under a stereomicroscope. The oribatid mite specimens were separated with

the help of a moistened camel hair brush and kept in 70% alcohol contained in a cavity block.

III. Preparation of Oribatid Mites for Taxonomic Studies

(i) Dehydration and Clearing

The oribatid specimens recovered through Open Brass funnel extraction/ direct examination/ washing method/and preserved in 70 % alcohol were transferred into cavity blocks/ watch glasses and sorted out using a fine needle and the camel hairbrush under 10x and 40x magnification of a Stereozoom microscope (Leica ES2 and Macro Vis, USA) and the mite specimens were then dehydrated by upgrading in alcohol series (80%, 90%, and 100%) and finally transferred to cap eppendorf vials containing clearing medium prepared by mixing absolute alcohol and lactic acid in the ratio 1:1. The time taken for clearing depended on the sclerotization of the mite species.

(ii) Slide Mounting

The cleared specimens were then slide mounted in various mounting media. For easy examination, temporary mounts were prepared in glycerin or lactic acid. Permanent mounts were made in polyvinyl alcohol/Hoyer's medium (Baker and Wharton, 1952)

A. Preparation of Mounting Media

a. Polyvinyl Medium

1. Elvanol 74-24 (Du port polyvinyl alcohol) was dissolved in 4 volumes of water at 90⁰C.
2. Then the solution was filtered.
3. Concentrated the clear filtrate on a water bath until the solution became syrupy.
4. 22 parts of lactic acid were added to 56 parts of the PVA solution and used for slide mounting.

b. Hoyer's Medium

- 1) Chloral hydrate -200 gms
 - 2) Gum arabic - 30 gms
 - 3) Distilled water - 50 ml
 - 4) Glycerine - 20 ml
- I- Transferred items (1&2) into 1000ml beaker
- II- Added 50ml of distilled water
- II- Added 20ml of glycerin and mixed well at room temperature

IV- Mixture filtered, and used for mounting.

- a) **Temporary Mounting:** Temporary slide mounts were prepared either on normal glass slides or in cavity slides for examination of morphological features and for easy identification of the species, by making ready comparison of key characters.
- 1- **Normal slide mounting:** For this, a drop of glycerin was placed at the center of a clean microscopic slide. The mite specimen was then transferred carefully into the glycerin drop to avoid air bubbles and to keep the specimen well immersed in the glycerin drop. The specimen was then properly oriented and a glass bristle of slightly larger size than that of the mite specimen was placed near the specimen. The glass bristle would serve to avoid the crushing of the specimen on mounting and ensure better orientation of the specimen so as to reveal the desired characters. A round cover glass of 18 mm diameter was then carefully placed over the specimen, without trapping any air bubbles.
- 2- **Cavity slide mounting:** This method necessitated the use of a clean cavity slide, in place of the normal glass slide discussed above and a round coverslip. The mite specimen was kept inside the cavity at the center, and then added a drop of glycerin. After properly orienting the specimen, slightly larger glass bristle was placed adjacent to the

specimen and coverslip was applied without trapping any air bubbles.

Excess glycerin was wiped out with a tissue paper.

b) Permanent Mounting:

Permanent slides were prepared either by using polyvinyl alcohol or Hoyer's medium (Baker and Wharton, 1952). The specimen was placed in the centre of a clean slide with the help of a fine Camel hairbrush. It was then aligned in the desired position using glass bristles, and covered by a coverslip. The mounted slides were kept at 50°C in an oven/incubator until the desired clarity was attained. The cover glass was sealed with commercially available nail polish, labeled properly and stored in slide boxes.

(iii). Scanning Electron Microscopy (SEM)

SEM images of selected species of mangrove dwelling oribatid mites were taken at the National Institute of Technology (NIT), Calicut by using Hitachi SU6600 Variable Pressure Field Emission Scanning Electron Microscope (FESEM).

IV. Identification of Oribatid Species

Identification of slide mounted specimens of oribatid mites was made under a Carl Zeiss research microscope by following the identification keys of Balogh and Balogh (1992 and 2002). Further, relevant literature/data on various taxa of oribatid mites were also referred for identification and

confirmation of taxonomic position of the species involved. Help from renowned oribatid taxonomists /experts outside India also was sought for confirmation of species with doubtful taxonomic status. Drawings of the various species included in the study were made with the help of a prism type Camera Lucida attached to a Unitron research microscope. Measurements of the specimens were made using an ocular micrometer and recorded in a calibrated micrometer.

Taxonomic rank and present systematic position of the various species assigned by following the most recent World Catalogue of Oribatid Mites published by Subias (2004) updated in 2015.

CHAPTER 4

GENERAL EXTERNAL MORPHOLOGY AND TERMINOLOGY OF ORIBATID MITES

Oribatid mites represent a group of mites with extreme diversity in morphology, habits, habitats, and the function. The very cryptic nature of these mites coupled with the possession highly sclerotized body with extreme structural complexity elicit a negative impact, hindering the progress in studies on this group of mites. In the present section, a concise report on the general external features of oribatid mites has been presented with an intention to impart a general awareness on the morphology of these mites, even to the beginners of oribatidology.

General External Morphology:

The body of all taxa of oribatid mites is mainly divided into 2 regions. i) An anterior **Proterosoma** and ii) a posterior **Hysterosoma**. The proterosoma or prosoma or propodosoma is covered dorsally by a shield called **prodorsum** and the shield covering the hysterosoma is called the notogaster. A **dorsosejugal suture** separates the propodosoma and hysterosoma, which may or may not be present always, and often it is interrupted in some species. The hysterosoma is divided into an anterior **podosoma** (the region bearing legs 1-4 together) and a posterior

opisthosoma. The **podosome** again can be distinguished in to two regions viz. the **propodosoma** (the region which bears the 1st and 2nd pairs of legs) and the **metapodosoma** (the region bearing the 3rd and 4th pairs of legs). The structures often found at the antero-ventral region constitute the **gnathosoma**.

1. Dorsal Region (Plate-10, Fig.1)

A. Prodorsum

The prosoma with anteriorly tapering triangular shield is called the **prodorsum**. Its frontally pointed structure is the **rostrum**, the edge of which bears teeth or incisions. Surface of prodorsum shows variation with respect to species but it may be ornamented with diverse cuticular structures of varying size and shape. A pair of blade like, free edged longitudinal structures are present medially or laterally on the prodorsum, called the **lamellae** and the tip of the lamella is generally called as the **cuspis**. The lamellae run forward from the bothridum and often, a ridge like **translamella** connects the lamellae of both sides. If the lamellae are simple structures with low ridges, then they are called the **costulae**. A narrow band called the **prolamella** runs distally towards the rostrum. Laterally, the prodorsal surface is provided with a pair of deep, cup like structures called **bothridia (bo)**. The prodorsum carries 6 pairs of mechanoreceptive setae as described below.

1. Rostral setae (*ro*) –are the anteriormost setae, inserted on the rostral tectum, if they present.
2. Lamellar setae (*le*) –posterior to seta *ro*, inserted at or anterior end of the lamellae.
3. Interlamellar setae (*in*) –the most proximal setae, of the three pairs, inserted in a space in between lamellae.

There are 2 pairs of exobothridial setae, located ventrolateral to each bothridium.

4. Anterior exobothridial setae (*exa*) –inserted anterior to bothridium.
5. Posterior exobothridial setae (*exp*)- inserted posterior to bothridium.
6. Sensillus (*ss*)-also called as the pseudostigmatic organ, is inserted within the bothridium.

This structure is present in most groups of oribatid mites, but may be absent in certain. Sensillus assumes different shape, size and nature, may be clavate, calyciform, setiform, pectinate, lamelliform, spatulate and fusiform etc.

B. Notogaster

Notogaster is a cap like sclerite separated from the prodorsum by a circumgastric scissure, or a groove called the **dorsosejugal furrow**.

Notogaster may be flattened, laterally compressed, hemispherical, hexagonal, pentagonal, concave, round or oval, according to groups. The cuticular surface of the notogaster may be smooth, or ornamented with conspicuous tubercles or foveoles. The anterio-lateral margin of notogaster displays a “shoulder” like excrescence called the **pteromorph** which is either immovable or movable.

Grandjean (1934a) provided setal notations according to segmental origin. Oribatids present great variations in the number and patterns of notogastral setae (chaetotaxy) which is significant in identification of different groups. Thus, the number of setae in oribatids may be 10, 14, 15, or 16. In some groups, the number of setae shows great difference, reaching such conditions like the neotrichy, characterized by the presence of numerous setae. The terminology of setae shows variation depending up on the number of setae.

B.1. Terminology of Notogastral setae

i) Oribatids with 10 Pairs of Setae.

1st row: *ta, te, ti*

2nd row: *ms*

3rd row: *r₁, r₂, r₃*

4th row: *p₁, p₂, p₃*

Where *a* represents anterior, *e* for exterior, *i* for interior.

ii) Oribatids with 14 or 15 pairs of Setae.

1st row: c_1, c_2, c_3

2nd row: da, la

3rd row: dm, lm

4th row: dp, lp

5th row: h_1, h_2, h_3

6th row: ps_1, ps_2, ps_3

Where 3 pairs are the dorsocentral (da, dm, dp) setae and other 3 pairs are the dorsolateral setae (la, lm, lp) and *a* denotes anterior, *m* median, *p* posterior and *h* humeral.

B.2. Types of Setae (Plate-11; Figs. 1-15)

The nature of notogastral setae in oribatid mites varies from one species to another, often specialized to different forms and which are classified by various authors (Mahunka and Zomberi, 1985; Walter, 2005).

1. **Arboriform:** branching type, resembling a tree, (Plate -11, Fig. 1)
2. **Clavate:** with a terminal swelling or knob (club –shaped; globose; capitate).(Plate-11, Fig. 2)

3. **Flagelliform:** Long, whip like, irregularly bending, slender like a thread, (Plate -11, Fig. 3)
4. **Foliate:** Slightly broad based, broadest in the middle, gradually tapering to a point, shaped like a leaf. (Plate-11, Fig 4)
5. **Setiform:** Slender, gradually tapering apically, bristle- like (Plate -11, Fig. 5)
6. **Spiniform:** Broad based, shaped like a spine or thorn. (Plate -11, Fig. 6)

Classification of Setae based on Specialized Ornamentations:

1. **Brocate:** With very fine bristles towards the tip. (Plate -11, Fig. 7)
2. **Ciliate:** Irregularly covered with fine hairs or cilia. (Plate- 11, Fig. 8):
3. **Pectinate:** Unilaterally beset with hairs or bristles arranged, resembles a comb. (Plate -11, Fig. 9)
4. **Pennate:** Bilaterally densely fringed with long fine hairs resembling a feather. (Plate -11, Fig. 10)

Classification of Setae with Marginal Variations:

1. **Barbed:** Densely covered with short bristles, like a stubby, unshaven face. (Plate -11, Fig.11)

2. **Ciliate:** Provided with fine cilia. (Plate- 11, Fig. 12)
3. **Entire:** With an even margin, without any kind of indentation. (Plate - 11, Fig. 13)
2. **Serrate:** notched on the end like a saw. (Plate -11, Fig.14)
5. **Spinose:** Having spine like projections or spines. (Plate- 11, Fig. 15)

Classification of Setae with Specialized Apices and Endings.

1. **Acuminate:** Strongly tapering to a point. (Plate -12, Fig. 1)
2. **Acute:** Having a sharp point. (Plate -12, Fig. 2)
3. **Conical:** Shaped like a cone or unbounded surface. (Plate 12, Fig. 3)
4. **Obtuse:** Having a blunt apex. (Plate -12, Fig. 4)
5. **Rounded:** Assuming a round shape. (Plate -12, Fig.5)

Classification of Setae with their Surface Ornamentations.

1. **Barbed:** Completely covered with fine hairs. (Plate -12, Fig.6)
2. **Ciliate:** With uniformly distributed cilia. (Plate-12, Fig.7)
3. **Glabrous:** Completely lacking hairs or bristles, smooth skinned. (Plate - 12, Fig.8)

4. **Plumose:** Densely covered throughout with long fine hairs. (Plate -12, Fig.9)
5. **Roughened:** Having an uneven or irregular surface. (Plate -12, Fig.10)
6. **Spinose:** Covered with strong, pointed spines, or thorn like structure. (Plate -12, Fig.11)

In oribatid mites, besides the setae, several other structures including special respiratory and sensory organs are present on the notogaster as listed below:

1. **Area Porosae:** These are porose organs, thinner than the notogastral cuticle. In higher oribatids, these dermal glands are of 4 pairs (Aa , A_1 , A_2 , A_3). They also vary in size, shape and nature and may be divided into 2 or more parts. In some groups, they are located at the dorsosejugal region as well as at the lamellar regions of the prodorsum.
2. **Sacculi:** These are small pockets sunken in to a body opening by pores of small dot or slit. These are represented as Sa , S_1 , S_2 and S_3 .
3. **Lyrifissures:** Sacculi like structures in the form of small slits are called lyrifissures. There are 5-7 pairs of notogastral lyrifissures present in most oribatids and which are denoted as ia , im , ip , ih , ips , iad and ian . Sometimes these are represented as less well-specified as a clear spot.

4. Opisthonotal Glands: A pair of oil glands (*gla*) with their duct opening in the mid- lateral region of the notogaster.

B.3. Notogastral Ornamentations in Oribatids (Plate-13; Figs.1-10)

In oribatid mites, the notogastral integument shows variations in micro sculpture. It has great importance in taxonomic point of view. These ornamentations differ from one species to the other.

1. **Alveolate:** Furnished with large, mostly round cells or spaces.(Plate - 13, Fig.1)
2. **Foveolate:** Having deep depressions or small pits, interspaces larger than diameter of one pit. (Plate-13, Fig.2)
3. **Granulate:** Covered with small rounded elevations or grains. (Plate - 13, Fig.3)
4. **Maculate:** Marked with angular spots or marks of irregular outline and of different size. (Plate -13, Fig.4)
5. **Polygonate:** Having fine granules, grouped into polygonal masses. (Plate -13, Fig.5)
6. **Punctate:** Marked with points or dots. (Plate -13, Fig.6)
7. **Punctulate:** Marked with minute points or dots. (Plate -13, Fig.7)
8. **Reticulate:** Forming a fine network or reticulum. (Plate-13, Fig.8)

9. **Rugose:** Covered with wrinkles. (Plate -13, Fig.9)
10. **Rugulose:** Covered with rather fine wrinkles. (Plate -13, Fig.10)

3. Lateral Side

A blade like chitinous ridge is present on each lateral side of the prodorsum called the tutorium (*tu*). A sac- like tectum originating around the insertions of leg I , leg II and rarely leg III is called pedotectum (pd_1 and pd_2 , pd_3). The ventral plate possesses a triangular structure, developed as a projection at the base of leg IV on each side, called the discidium (*dis*), which has a similar as that of the pedotectum. In some oribatids, a triangular crista arises from leg IV, called the custodium (*cus*), often occurs between acetabula III—IV, and a paired circumpedal carina may curve anteromedially from the edge of the ventral plate, running behind leg IV and forward across epimera IV and III.

4. Ventral Region (Plate-10; Fig.2)

This region consists of the gnathosoma, epimeral region and the anogenital regions.

4.1. Gnathosoma

Gnathosoma is the region bearing the mouthparts and is located in an anterior cavity called the camerostome. Mouthparts include the subcapitulum or infracapitulum, paired chelicerae and paired pedipalps. Infracapitulum is

the basal part of the gnathosoma, which consists of an unpaired mentum (hysterosoma), and paired genae laterally, which continue to form the rutellae. The articulation between the mentum and genae is known as the labiogenal articulation and which may be one of the 4 types:

Anarthric type: Devoid of any specialized articulations

Stenarthric: Labiogenal articulation is present and is directed posteriorad and hence the mentum is triangular in appearance.

Diarthric: Labiogenal articulation is transverse and mentum is large.

Suctorial: Mentum and genae are fused, without any suture. Also the rutelli are modified into tubes.

Infracapitular region bears setae, which are varying in number, shape and size. Usually, mentum and genae bear one pair of setae each (*h* and *a* respectively). In higher oribatids, usually only a single pair of minute seta (*m*) present. In addition to this, genae also bear 1-2 pairs of minute setae (*m*₁ and *m*₂), in primitive forms. Pedialps bear 2-5 segments each. The chelicerae may be of two types: i) wide chewing type and ii) picking, or peloptoid type. Chewing type of chelicerae possess two setae, (*cha* and *chb*), and a fixed digit (digitus fixus) and a movable digit (digitus mobilis), bearing varying number of teeth.

4.2 Epimeral Region

The epimeral or coxisternal region is the area between the infracapitulum and the genital region. This region is covered by 4 epimeral plates viz. ep_1 , ep_2 , ep_3 and ep_4 which is connected with legs I-III and extends to the genital opening. The epimeral plates are bordered by continuous thickenings called the apodemata. Generally, 5 apodemata are present. apo_1 , apo_2 , ap_3 , ap_4 and the sejugal apodeme $apoj$. The number of epimeral setae varies and are usually denoted in the form of a formula (epimeral setal formula) of four figures.

4.3 Ano-genital Regions

These regions lie posterior to the epimeral region and carry the genital and anal plates. In primitive (Macropyline) groups of oribatid mites, the genital and anal plates touch each other and occupy the entire length of the ano-genital region in the form of a “U” and “Y”. However, in higher oribatids (Brachypyline), the genital and anal plates do not meet each other and are placed on a distinct ventral plate. A pair of genital plates, an unpaired pre-anal plate, a pair of anal plates and a pair of laterally located adanal plates are seen on the ventral plate. Genital plates carry a maximum of 10 pairs of setae. The number of aggenital, anal and adanal setae vary among species. The genital and anal areas may also have porous areas and slit organs (fissure *iad*). The ventral plate may be ornamented variously.

4.4 Legs

Adult mites possess 4 pairs of legs, inserted in to the acetabuli. Each leg is composed of 5 free segments viz. trochanter, femur, genu, tibia and tarsus. The leg segments possess varying numbers of setae, including both the tactile and sensory setae. Chaetotaxy of legs varies from species to species and is usually represented by a formula.

The leg setae are of 4 types.

- 1) **Normal Setae:** These are homogenous with a very small median cavity and contain actinochitin. These setae usually occur in pairs. (Plate 12, Fig.12)
- 2) **Solenidia:** Hollow, optically inactive and chemosensory setae, often a series of concentric rings are visible around them, under higher magnification. Solenidia are designated with Greek letters, ω (omega) on the tarsus, ϕ (phi) on the tibia, and σ (sigma) on the genu. (Plate 12, Figs.13-16)

Solenidia are of the following 4 types:

- (a) **Baculiform:** having the same diameter throughout, rod- shaped.
- (b) **Ceratiform:** tapering towards the tip
- (c) **Piliform:** elongated with fine tip.

- (d) **Tactile:** very long and flagellate.
- 3) **Eupathidia:** represent modified homologous setae, which are optically active, hollow structure restricted to the tarsi alone and it is designated by zeta (ζ).
- 4) **Famuli:** hollow, unique structures found only on tarsal segments, containing actinochitin. Their internal surface is rugose and usually seen very close to a solenidion. Famuli are represented by the Greek letter, epsilon (ϵ)

The tarsal segment terminally carries a pretarsus with 1-3 claws on a short peduncle. Depending up on the shape and number of claws , legs are of 3 types.

1. **Homodactylous:** with 3 claws, all of equal size.
2. **Hetero-tridactylous:** with 3 claws in which the central or the empodial claw is larger and thicker than the 2 lateral ones.
3. **Monodactylous:** with a single claw.

The claws may be simple, smooth, or may be provided with very short spines or teeth.

CHAPTER 5

OBSERVATION

Results of the field sampling carried out from the various the mangrove ecosystems of North Kerala disclosed the presence of 23 species belonging to 21 genera, 16 families and 10 Superfamilies (Table.4). The Superfamily Oripodoidea showed the maximum diversity, comprising members of 6 families viz. Oribatulidae, Hemileiidae, Scheloribatidae, Oripodidae, Protoribatidae and Haplozetidae. Of these, maximum genera of oribatid mites could be recovered under the family Lohmanniidae, followed by Haplozetidae and Austrachipteriidae. The superfamily wise representation of the mangrove inhabiting oribatids recovered during the present study could be presented as (Plate14; Fig.1-2):

Oripodoidea>Ameronothroidea> Cosmochthonioidea= Lohmannioidea=
Euphthiracaroidae= Phthiracaroidae=
Crotonioidea=Carabodoidea=Limnozetoidea=Galumnoidea.

Among the 23 species recovered from the various mangrove ecosystems distributed over Malappuram, Kozhiloode, Kannur and Kasaragod districts of North Kerala, 6 species and 1 genus could be identified as new to science. The new genus erected during the present study was *Holocarinozetes* gen.nov. under the family Fortuyniidae. The 6 new species described during

the study were *Haplacarus aureus* sp.nov. (Lohmanniidae), *Selenoribates mangrovius* sp.nov. (Selenoribatidae), *Holocarinozetes epimeratus* gen.nov.sp.nov.(Fortuyniidae), *Phauloppia kadalundiensis* sp.nov. (Oribatulidae), *Protoripoda (Protoripoda) trifolius* sp.nov.and *Trachyoribates (Rostrozetes) nortoni* sp.nov.(Haplozetidae). The species collected under the family Lohmanniidae were *Annectacarus unilateralis* Hammer, 1973; *Heptacarus hirsutus* Wallwork, 1964; *Javacarus (Javacarus) porosus* Hammer, 1979 and *H. aureus* sp.nov. The species collected under Haplozetidae were *Indoribates (Indoribates) punctulatus* (Sellnick, 1925) and *T.(R.).ovulum ovulum* Berlese, 1908 and *T.(R.)nortoni* sp.nov. The species collected under Trhypochthoniidae were *Afronthrus arboreus* Ramani and Haq, 1992 and *Archeogozetes longisetosus* Aoki, 1965. The family Austrachipteriidae was represented by *Lamellobates (Lamellobates) molecula* Berlese, 1947 and *L.(Paralamellobates) bengalensis* Bhaduri and Raychaudhuri, 1968. The families Cosmochthoniidae, Euphthiracaridae, Phthiracaridae, Carabodiade, Selenoribatidae, Fortuyniidae, Oribatulidae, Hemileiidae, Scheloribatidae, Oripodidae, Protoribatidae and Galumnidae were represented by a single species each (Table.4).

Apart from the detection and description of a new genus and 6 new species, the results of the study also helped to distinguish 14 species belonging to 13 genera and 10 families as new records from the mangrove ecosystems. The newly recorded mangrove inhabiting species were A,

unilateralis, *H. hirsutus*, *J. (J.) porosus*, *A. clavata*, *Hoplophorella* (*Hoplophorella*) *vitrina*, *A. arboreus*, *A. longisetosus*, *Carabodes* (*Klapperiches*) *penicillus*, *L. (P.) bengalensis*, *Siculobata* (*Siculobata*) *malabarica*, *Protoribates* (*Protoribates*) *capucinus*, *I. (I.) punctulatus* and *Galumna* (*Galumna*) *paragibbula* .

The distribution pattern of the oribatid species collected showed variation with respect to the differences in the site characteristics like the vegetational, geographical and climatic features. The mangrove ecosystems located in the Malappuram Dt. disclosed the presence of 5 species belonging to 4 genera, 4 families and 3 superfamilies (site1) and 4 species belonging to 4 genera, 4 families and 3 superfamilies (site 2). Families like Austrachipteriidae and Haplozetidae showed the maximum generic representation, comprising members of 2 genera each. Members of 1 genera could be recovered under Lohmanniidae from the collection sites of Malappuram Dt. and the remaining families viz. Phthiracaridae, Scheloribatidae and Protoribatidae were represented by one genus each. The generic diversity of the various oribatid families recovered from the sites of Malappuram Dt. could be presented as follows:

Austrachipteriidae=Haplozetidae>Lohmanniidae=Phthiracaridae
=Scheloribatidae=Protoribatidae

In Kozhikode Dt, the sites 1 and 2 disclosed the presence total of 14 species, representing 14 genera, 13 families and 10 superfamilies. The species diversity of oribatids in the mangrove ecosystems in the Kozhikode Dt. (Sites 3-7) was comparatively high. The selected mangrove sites in this district showed unique vegetational and geographical characteristics. As shown in table 6, a total of 19 species belonging to 17 genera, 13 families and 10 superfamilies could be recovered from the all the sites together, from this district. Sites 3 and 4 supported both true and associate mangrove vegetation, from which 14 species belonging to 14 genera, 13 families and 11 superfamilies could be collected. These sites were found to harbor several new taxa of oribatids such as *Holocarinozetes* gen.nov., *H. epimeratus* gen.nov.sp.nov. (Fortuyniidae), *P.kadalundiensis* sp.nov. (Oribatulidae) and *P.(P.) trifolius* sp.nov. Sites 5-7 were represented by small mangrove patches, which on screening enabled to collect a total of 8 species under 7 genera, 4 families and 3 superfamilies, including 2 new species viz. *H. aureus* sp.nov. (Lohmanniidae) and *T. (R.) nortoni* sp.nov.

Based on the generic diversity of the oribatid mites, the mangrove dwelling oribatid families of the various sites in the Kozhikode Dt. could be represented as follows:

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Hemileiidae =Scheloribatidae=Oripodidae=Protoribatidae= Galumnidae

The family Lohmanniidae included the maximum genera (4 genera) comprising species viz. *H. hirsutus*, *A.unilateralis*, *H. aureus* sp.nov. and *J. (J.)porosus*. The families Austrachipteriidae and Haplozetidae were represented by 2 genera each, and families like, Cosmochthoniidae, Euphthiracaridae, Phthiracaridae, Trhypochthoniidae, Carabodidae, Oribatulidae,Hemileiidae, Scheloribatidae and Protoribatidae were represented by a single genus each.

The results sampling carried out from the various mangrove ecosystems of Kannur Dt. (sites 8-14) brought out the presence of 15 species grouped under 14 genera, 11 families and 9 superfamilies. A truly intertidal new species viz. *S. mangrovius* sp.nov. (Selenoribatidae) also could be recorded from site 13 of this Dt. The various oribatid families could be could be arranged in the following sequence, based on the number of genera included under each.

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Of these, the family Lohmanniidae was found represented by 3 genera, while Austrachipteriidae and Haplozetidae included 2 genera each and the families Euphthiracaridae, Phthiracaridae, Trhypochthoniidae, Carabodidae,

Selenoribatidae, Scheloribatidae, Protoribatidae and Galumnidae were found to comprise a single genus each.

The single site screened from the Kasaragod Dt. (Site-15) revealed the presence of 5 species belonging to 5 genera, 5 families and 4 superfamilies and according to the variations in the generic diversity, the above families could be arranged in the following order.

Cosmochthoniidae = Euphthiracaridae = Trhypochthoniidae =

Austrachipteriidae = Haplozetidae

The species diversity of the mangrove dwelling oribatids included in the 15 sites could be presented as

Site 3 = Site 4 > Site 13 > Site 1 = Site 8 = Site 15 > Site 2 > Site 5 = Site 6 = Site 12 = Site 14 > Site 7 = Site 10 > Site 11 (Table. 5; Plate, 14, Fig.3)

During sampling, both the adult and immature stages of various oribatid species were recovered from dead leaves of true and mangrove associates, and from their litter including twigs, barks, dead pneumatophores, and also from algal cushions attached to pneumatophores and other mangrove litter substrates. In the present study, members of some truly intertidal oribatid families like Fortuyniidae and Selenoribatidae could be recorded for the first time from the mangrove ecosystems of oriental region, especially from the Indian subcontinent.

CHAPTER 5

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CHAPTER 7

DESCRIPTION OF SPECIES

Infraorder: Enarthronota Grandjean, 1947

Superfamily: Cosmochthonioidea Grandjean, 1947

Family: Cosmochthoniidae Grandjean, 1947

Genus: *Cosmochthonius* Berlese, 1910

Subgenus: *Cosmochthonius* (*Cosmochthonius*) Berlese, 1910

Generic Diagnosis

Slightly convex in shape, notogaster with 3 transverse sutures, thereby subdivided into 4 shields; notogastral setae setiform, with more or less elongated cilia; setae of 'e' and 'f' long and erectile, resembling palm-leaves, setae of row 'c' arising on shield NA, row 'd' on shield NM, row 'e' found in transverse suture, seta *f* in third transverse suture, setae *b* and *ps* on shield PY; prodorsal setae and rows 'h' and 'ps' short or medium, densely ciliate or plumose; 10 pairs of genital, 4 pairs of anal and adanal setae present; claw formula of legs 2-3-3-3.

***Cosmochthonius* (*Cosmochthonius*) *reticulatus* Grandjean, 1947**

(Plate -15, Figs. 1-2)

Colour : Yellowish Brown

Measurements : Length: 280 µm

Width: 152 µm

Dorsal Region (Fig.1)**Prodorsum**

Prodorsum narrow, short and broadly conical with a ventrally curved rostrum, the latter without distinct teeth; prodorsal surface ornamented with large rounded foveoles; seta *ro* very thick, paint-brush in shape (Fig.1a), situated laterally on the prodorsum, seta *le* bifurcated to form a 'T' with a small posterior branch and a large anterior branch, thinner but resembles *ro* in nature, originating far beyond the rostrum (Fig.1b); seta *in* as long as *ro*, pyliform; seta *ex* small, thick and brush like; sensillus narrow at the base, progressively thickened along its length, clavate apically and densely setose at its tip; prodorsal surface covered with a thin layer of cerotegument.

Notogaster

Notogaster oval with a more or less straight anterior margin; small shoulder-like projection seen at the humeral region; hysterosoma divided into 4 segments by 3 transverse furrows, segment -I larger than segments -II and III but shorter than segment -IV, segment I carries 4 pairs of setae, setae c_1 and c_2 as long as cp , seta c_3 shorter than the other c setae; segment II bears 2 pairs of setae (d_1 and d_2), setae e_1 and e_2 very thick and long, inserted in the furrow separating segments I^t and II, seta f_1 longer than seta f_2 and originates from the third furrow, segment IV large, having marginally 4 short, thick pointed setae, all laterally compressed bearing long bristles laterally; notogastral ornamentation resembles that of prodorsum.

Ventral Region (Fig.2)

Epimeres well separated, all epimeral setae bilaterally feathered, epimeral setal formula 3-2-3-4; each genital plate with 10 setae, arranged linearly in 2 rows, an inner row of 6 and an outer row of 4, all setae serrate; both anal and adanal plates with 4 pairs of setae; aggenital setae absent.

Legs

All legs hetero-tridactylous with claw formula: 2-3-3-3.

Materials examined

A single ♂ collected from the rotten leaves of the true mangrove plant, *A. officinalis* growing in the mangrove ecosystems of Nileswaram (12°26'46.89"N 75°12'63.16"E), Kasaragod (Dt) of North Kerala on 11.11.2011, coll. P.K. Syamjith.

Remarks

Cosmochthonius is a cosmopolitan genus erected by Berlese (1910) based on the type species, *Hypochthonius lanatus* Michael, 1885. Presently, this genus includes 37 valid species. Results of taxonomic studies based on comparison of morphological features of the present specimen supplemented with the analysis of its SEM images enabled to confirm the resemblance of the species with the known species, *C. reticulatus* described by Grandjean (1947) and redescribed by Penttinen and Gordeeva (2005) in the following characters:

1. Number and nature of the notogastral grooves,
2. Nature of prodorsal and notogastral ornamentation,
3. Presence of humeral projection,
4. Nature of sensillus, prodorsal and notogastral setae and
5. Similarities in the epimeral setal formula and genital and ano-adanal chaetotaxy.

Superfamily: Lohmannioidea Berlese, 1916

Family: Lohmanniidae Berlese, 1916

Genus: *Annectacarus* Grandjean, 1950

Generic Diagnosis

Genital plates without transverse suture; pre- anal plate narrow; anal and adanal plates fused, presence of 2 pairs of anal and 4 pairs of adanal setae and absence of pygidial neotrichy.

***Annectacarus unilateralis* Hammer, 1973**

(Plate -16, Figs.1-2)

Colour : Light brown

Measurements : Length: 510 - 522 μm

: Width: 252-270 μm

Dorsal Region (Fig.1)

Prodorsum

Prodorsum punctate throughout, prodorsal surface ornamented with indistinct reticulate pattern; rostral border broadly incised antero- medially,

seta *ro* strong, straight, bilaterally barbed, setae *le* and *in* finely barbed unilaterally, setae *exa* and *exp* present, both barbed; sensillus (*ss*) pectinate, bearing 14 branches on one side and 6-7 branches on the other side; inter-lamellar area ornamented with polygonally arranged punctations; a few area porosae found scattered on prodorsum.

Notogaster

Anterior border of notogaster straight while the posterior border rounded; notogaster possesses 22 pairs of unilaterally barbed (fringed) setae; setae c_2 and d_2 moderately long and barbed, setae b_1 , b_2 , b_3 and b_4 shorter and thinner than c_2, d_2 ; seta f_1 similar to c_2 and d_2 ; foveoles present on lateral and posterior borders of notogaster.

Ventral Region (Fig.2)

Infracapitulum bears 4 pairs of setae, seta *a* smooth, while setae *h*, m_1 and m_2 barbed and thick; epimeral neotrichy present with an epimeral setal formula of 6-4-3-4, setae *1a*, *2a*, *3a* short, seta *4a* little longer and finely barbed; genital plates bear 10 pairs of barbed setae, 4 pairs of laterally arranged and 6 pairs of medially arranged setae, lateral setae longer than the medial ones; pre-anal plate narrow with parallel sides; ano-adanal plates fused bearing 2 pairs of thinner, shorter, apparently bilaterally fringed anal hairs and 4 pairs of long, bilaterally fringed, adanal setae, adanal plates punctate while anal plates smooth; dense aggregates of punctuations present in some areas of the ventral plate; fissures *ia*, *ih*, *ip* and *ips* detected.

Legs

All legs monodactylous with punctations on all segments, arranged in a reticulated pattern; femur I stout with an antero- ventral keel and a ventral notch.

Materials examined

3♂♂ and 4♀♀ collected from the soil and litter samples of the mangrove ecosystems of Mankavu (11°14'7.69"N 75°48'13.52"E), Kozhikode (Dt.) on 19.3.2012, and Koduvalli (11°45'59.30"N 75°28'42.06"E), Kannur (Dt), North Kerala on 5.5.2011. coll. P.K. Syamjith.

Remarks

The present specimens resemble *A. unilateralis* described by Hammer (1973) from the Tonga Islands in the general appearance, nature of prodorsal setae and shape and nature of notogastral setae. It is the first report from the mangrove ecosystems of India, especially from Kerala.

Superfamily: Lohmannioidea Berlese, 1916

Family: Lohmanniidae Berlese, 1916

Genus: *Haplacarus* Wallwork, 1962

Generic Diagnosis

Genital plates without transverse suture; pre- anal plate broad; anal and adanal plates fused, 1pair of anal and 4 pairs of adanal setae present; notogastral and epimeral regions without neotrichy.

***Haplacarus aureus* sp.nov.**

(Plate -17, Figs.1-3)

Colour	: Golden Yellow
Measurements	: Length: 652 μ m (650-720 μ m)
	: Width: 310 μ m (302-352 μ m)

Dorsal Region (Fig.1)

Prodorsum

Anterior border of prodorsum smooth, without any incision; all prodorsal setae barbed, seta *ro* directed forward, measures 75 μ m, inserted far behind the rostral tip; seta *le* long, inserted below the insertion point of *ro* and measures 94 μ m, curved laterad; seta *in* long and thick measuring 110 μ m, placed below the level of bothridium (*bo*); setae *exa* and *exp* measure 104 μ m and 94 μ m respectively, *exp* falcate; a band formed of small papillae runs between setae *in*; bothridium (*bo*) cup shaped; sensillus (*ss*) pectinate with 10-11 branches; prodorsal integument covered with small tubercles.

Notogaster

Notogaster elongated with wavy margins; microsculpture of notogaster comprised of small uniformly distributed golden coloured tubercles; 16 pairs of notogastral setae present, all thickened and weakly foliate; setae at the posterior margin slightly barbed; seta *ps*₁ incurved with distal ends; 9

notogastral bands formed of clear areas present, of which 4 bands (S_2 , S_3 , S_5 and S_6) interrupted/or medially broken.

Ventral Region (Fig.2)

Infracapitulum with 4 pairs of setae, a , h , m_1 and m_2 , all setae foliate, thicker and slightly dentate; mentum ornamented with round tubercles medially; epimeral setal formula 3-1-3-4, all setae roughened, rather thick and with minute barbs, epimeral surface ornamented with small round tubercles, micropunctations; aggenital plates located at the antero-lateral corner of the genital field, genital plates without transverse suture, each plate carries 10 pairs of setae, paraxial row of 6 small, and antiaxial row of 4 elongate, thick setae; 1 pair of anal and 4 pairs of adanal setae inserted on the fused ano-adanal plates, all setae foliate with distinct barbs, anal setae thinner and smaller than the adanal ones; fissures ia , ip and ih detected in the normal positions.

Legs

All legs monodactylous; femora of all legs possess raised, rounded tubercles; chaetotaxy of leg I (Fig.3): 0-4-4-3-18, femur- I with a thick, foliate and barbed seta d and a smooth seta, l ; setae bv and v thick, foliate and barbed; genu -I bears two solenidia, σ_1 and σ_2 , seta l' thick and barbed; tibia -I with a long solenidion φ , setae xt_1 and xt_2 thick and barbed; tarsus -I carries 18 setae including 2 solenidia ω_1 and ω_2 .

Materials examined

Holotype ♀; paratypes: 1 ♂ and 4♀♀ collected from the soil/ litter samples of the mangrove ecosystems at Kottakkadavu, (11°8'15.99"N and 75°50'28.26"E.), Calicut (Dt) of North Kerala on 08.10.2013, coll. P.K. Syamjith.

Type repository

The type specimen will be deposited at the Zoological Survey of India (ZSI) Calicut, Kerala, India.

Etymology

The specific name is derived based on the beautiful, golden colour of the specimen.

Remarks:

The genus *Haplacarus* was erected by Wallwork (1962) based on the type species, *H. foliatus*. Presently, the genus contains 11 valid species (Subias, 2015) viz. *H. foliatus* Wallwork (1962), *H. pairathi* Aoki (1965), *H. javensis* Hammer (1979), *H. pandanus* Sengbusch (1982), *H. bhadurii* Sanyal (1984), *H. maharashtraensis* Sanyal (1984), *H. keralensis* Haq, Mubarak & Ramani (1984), *H. rugosus* Mahunka (1987), *H. porosus* Haq & Clement (1995), *H. davisii* Xavier, Haq & Ramani (2005) and *H. xavieri* Xavier, Haq & Ramani (2005). The present species, *H. aureus* resembles the known species in the general appearance, number and disposition of prodorsal and notogastral hairs as well as most of the ventral features. However, the

possession of 4 incomplete notogastral bands in the new species easily separates it from the known species viz. *H.xavieri* (5 incomplete bands), *H.foliatus*, *H.pairathi*, *H.pandanus* (3 incomplete bands each), *H.javensis*, *H.bhadurii*, *H.maharashtraensis*, *H.keralensis* (2 incomplete bands each), *H.porosus* (all the 9 bands complete) and *H. davisii* and *H.rugosus* (fused nature of the 2 incomplete bands). The possession of 10-11 branched sensillus of the present species helps its easy separation from other known species like *H.javensis* (8 branches), *H.bhadurii*, *H.maharashtraensis* (7 branches each), *H. rugosus* (12-14 branches); *H.porosus* & *H.xavieri* (14-15 branches each), *H.foliatus*, *H. keralensis* and *H. pandanus* (10-12 branches each). The bright golden coloured, tuberculated body and falcate nature of seta *exa* are the unique features of the present species which help its segregation from all the known species and its erection as a new species under the genus *Haplacarus*.

Superfamily: Lohmannioidea Berlese, 1916

Family: Lohmanniidae Berlese, 1916

Genus: *Heptacarus* Piffel, 1963

Generic Diagnosis

Genital plates with transverse suture; anal and adanal plates fused, pre-anal plate broad; 2 pairs of anal and 5 pairs of adanal setae present; pygidium with neotrichy; 27 to 60 pairs of notogastral setae present; epimeral region with weak neotrichy.

***Heptacarus hirsutus* Wallwork, 1964**

(Plate- 18, Figs.1-2)

Colour	: Light brown
Measurements	: Length: 510 - 550 μm
	: Width: 246-252 μm

Dorsal Region (Fig.1)

Prodorsum

Rostrum broad, rounded; lateral margins of prodorsum produced into rather angular wings; seta *ro* slender and barbed, inserted close together dorsally; seta *le* also barbed, slightly longer and thicker than *ro*; seta *in* slender, finely barbed and as long as *le*, but resembles *ro*; 2 slender, finely barbed exobothridial setae (*exa* and *exp*) present on each lateral side of prodorsum; *bo* small, cup shaped, opened posterolaterally; *ss* pectinate with pectinations which become progressively longer towards the tip.

Notogaster

Notogastral bands absent; weak neotrichy in setal rows *c*, *d* and *e*, strong neotrichy present posterior to row *e*; all setae slender and richly barbed, moderately long, setae more elongated towards the posterior end of the notogaster; entire surface granulated.

Ventral Region (Fig.2)

Infracapitulum bears 4 pairs of setae, seta *h* pectinate, seta m_1 and m_2 barbed, but not pectinate; seta *a* longer than m_1 and m_2 ; epimeres I and II completely separated by the sejugal furrows, epimeral neotrichy absent, epimeral setal formula 3-1-3-4, all setae pectinate; pre-anal plate broad; genital plates divided by transverse suture, anterior half triangular and posterior half rectangular in shape; each plate bears 10 setae, paraxial row of 6 and antiaxial row of 4, antiaxial setae longer than the paraxials, all setae pectinate; aggenital plate triangular; ano-adanal plates fused bearing 2 pairs of slender, finely barbed anal and 5 pairs of pectinate adanal setae.

Legs

All legs monodactylous bearing a single stout claw; femora I-IV with well-developed ventral keels.

Materials examined

2 ♂♂ and 5 ♀♀ collected from the soil and litter samples of the mangrove ecosystems of Ezhome (12° 1'38.28"N and 75°17'0.72"E) and Koduvalli (11°45'59.30"N and 75°28'42.06"E) Kannur (Dt), North Kerala, India, on 16.01.2013, coll. P.K. Syamjith.

Remarks

The specimens examined presently resemble *H. hirsutus* described by Wallwork (1964) from Tchad Island in the nature and arrangement of

prodorsal, notogastral, genital, anal and adanal setae and in the presence of prodorsal wings. This forms the first report of the species from the mangrove ecosystems of India, especially from Kerala.

Superfamily: Lohmannioidea Grandjean, 1967

Family: Lohmanniidae Berlese, 1916

Genus: *Javacarus* Balogh, 1961

Subgenus: *Javacarus (Javacarus)* Balogh, 1961

Generic characters

Genital plates without transverse suture; anal and adanal plates fused, Pre-anal plate wide, anal setae absent; 4 pairs of adanal setae present; notogastral and epimeral regions without neotrichy.

***Javacarus (Javacarus) porosus* Hammer, 1979**

(Plate –19, Figs.1-2; Plate- 20, Figs.1-6)

Colour : Brown

Measurements : Length: 650-702µm

Width: 335-350µm

Dorsal Region (Plate-19, Fig.1; Plate-20, Figs.1-3)

Prodorsum

Prodorsum triangular in shape, anterior border of rostrum entire; seta *ro* measures 96 µm in length, straight and inserted far below the rostral apex; lamellar seta (*le*) dentate, inserted laterally, below the insertion point of *ro*

and measures 118 μm ; seta *in* 112 μm long, placed below the level of bothridium (*bo*); setae *exa* and *exp* measure 111 μm and 86 μm respectively, *exp* falcate in nature; all other prodorsal setae foliate with distinct midrib and faintly dentate in nature; a band runs in between setae *in* of either side; a pair of lateral ridges present; *bo* cup shaped; *ss* pectinate with 10 branches; integument covered with raised tubercles medially.

Notogaster

Lateral margins of notogaster parallel and posterior region globular; notogaster bears 16 pairs of lanceolate and dentate setae; dorsal setae short with more or less blunt tip, marginal setae (c_3, d_3, h_3, ps_2 and ps_3) longer and thinner towards tip; seta c_1 directed forwards, seta e_2 short; seta ps_1 slightly incurved; 9 complete, irregular notogastral bands present; tubercles present in between the bands, particularly at the posterior region (Plate-20, Fig.3); a few area porosae located in between setae d_2 and e_2 .

Ventral region (Plate-19, Fig.2; Plate-20, Figs.4-6)

Intracapitulum with 4 pairs of setae *a*, *h*, m_1 and m_2 of which *a* and m_1 thin, m_2 and *h* thicker and dentate; epimeral setal formula 3-1-3-4, all setae roughened, rather thick and faintly dentate in nature; epimere-I bears a few area porosae, apodemes 1,2,3 and sejugal one (*apo.sj*) well developed; setae *1b*, *3b* and *4b* thicker and longer than the others; genital plates without transverse suture, each plate carries 10 setae, paraxial row of 6 small, smooth setae and anti-axial row of 4 long, roughened setae; pre-anal plate with a postero-median projection; ano- adanal plates fused; anal setae absent; adanal

setae 4 pairs, all setae foliate and roughened in nature; ventral integument covered with faint tubercles, particularly at the lateral areas of genital and paraproctal plates; fissure *ip* aligned near to the insertion point of seta h_3 ; base of all legs micropunctate; scattered cerotegument found adhered to the lateral regions of the ventral plate, exterior to the ano-adanal plate (Plate-20, Fig.5).

Leg

All legs monodactylous with a stout claw, all leg segments ornamented with small fine, raised micropunctations; chaetotaxy of leg I : 1-4-4(2)-4(1)-18(2), trochanter -I with a single roughened seta, femur I with thick and barbed setae *d* and *l''*, genu -I bears 2 solenidia, σ_1 and σ_2 , seta *l'* thick and barbed, tibia -I with a long solenidion φ associated with seta *d*, setae xt_1 and xt_2 thick and barbed, tarsus -I carries 18 setae, of which solenidion ω_1 thicker than ω_2 and with a blunt tip. Setae (*ft*) thick and barbed and *pv''*, *s*, *m''*, (*p*) and (*a*) smooth.

Materials examined

3 ♀♀ collected from the soil and litter samples of mangrove ecosystems of Thalassery (11°45'18.12"N and 75°29'30.58"E) Kannur (Dt) on 5.5.2012 and 2♂♂ and 5♀♀ from the mangrove litters of Kallai (11°14'16.72"N and 75°47'14.12"E) Kozhikode (Dt) on 2.4.2014. North Kerala, India, coll. P.K. Syamjith.

Remarks:

The genus *Javacarus* was erected by Balogh (1961) with the type species, *J. kühnelti*. At present, this genus includes 8 valid species. The

present specimen examination shows close resemblance to *J. (J.)porosus* described by Hammer (1980) from Java in most of the features. However, the nature of the prodorsal integument, nature of the epimeral setae and possession of scattered cerotegument on the lateral areas of the ventral plate, lying exterior to the ano-adanal plates are some of the variations observed in the present specimen. The recovery of the species forms the first report on the presence of the genus in the mangrove ecosystems of Kerala, India.

Superfamily: Euphthiracaroidae Jacot, 1930

Family: Euphthiracaridae Jacot, 1930

Genus: *Acrotritia* Jacot, 1923

Generic Diagnosis

Prodorsum without median carina, but with one or 2 lateral carina, bothridial scale lies above bothridium; notogaster with 14 pairs of setae erect, barely rough; ventral plate with 6 genital (rarely 8-9) and 2 aggenital setae, situated one behind the other; genitoaggenital and anoadanal plates completely fused, one interlocking triangle present.

***Acrotritia clavata* (Märkel, 1964)**

(Plate- 21 Figs.1-3; Plate-22, Figs.1-3)

Color: Dark brown

Measurement:

Length of Aspis: 230- 263 µm

Width of Aspis: 168 - 182µm

Length of Notogaster: 392- 480µm

Width of Notogaster: 366- 399µm

Dorsal Region (Fig.1)**Prodorsum****Aspis** (Plate- 21 Fig.1a; Plate-22, Fig.2)

Prodorsum with a pair of lateral carina; setae on aspis more delicate than those of other species of the genus, the posterior most pair conspicuously long and somewhat curved; length of setae range as: $in > le > ro > ex$; lamella incised medially and placed above bothridium; exobothridial setae small; sensilli with a narrow stalk and clubbed head, rough, almost smooth (Plate -22, Fig2); bothridium not distinctly spiral in top view, but appears as a distinctly spiral structure in semi-oblique view; entire prodorsal surface punctated (Plate-21, Fig.1a).

Notogaster

Notogaster with 14 pairs of fine, short, rigid setae, without sign of shagreen appearance, setae c_1 and c_2 considerably remote from anterior margin, setae c_3 closer to margin; opening of latero-opisthosomal gland distinct; 5 lyrifissures and 2 vestigial setae present on both sides, situated typically for the genus; it appears ornamented with punctations under higher magnification (400x).

Ventral Region (Plate- 21, Fig.2; Plate-22, Fig.3)

Infracapitulum with seta h longer than their mutual distance; palps 3-segmented with a setal formula of 2-2-7, palp tarsus carries a single

solenidion (ω); epimeral setal formula 3-1-3-3, all setae smooth and setiform; genito- aggenital plates almost smooth, genital plates carry 6 pairs of small, fine setae, 2 pairs of short, smooth aggenital setae, inserted one behind the other; 3 pairs of anal (an_{1-3}) detected, of which seta an_3 the smallest; 3 pairs of long, setiform adanal setae, ad_1 inserted conspicuously far from ad_2 and ad_3 ;

Legs

All legs monodactylous with strong claw, chaetotaxy of leg I (Pate-21, Fig.3): 3-2(2)-4(1)-15(1)

Materials examined

10 ♂♂ and 8 ♀♀ recovered from the dead pneumatophores/decaying barks of the mangrove plant, *A. marina* growing in the mangrove ecosystems of Kadalundi –Vallikkunnu community reserve (11° 7'34;13"N and 75°49'51;17"E), Calicut (Dt) of North Kerala on 12.01.2012, coll. P. K. Syamjith.

Remarks

The present specimen very closely resembles *A. clavata* described by Märkel, 1964 from Peru in the general morphology, nature and arrangement of prodorsal, notogastral, genital, anal and adanal setae. However, the prodorsal ornamentation shows slight variation. This forms the first report of the genus from the mangrove ecosystems of Kerala, India.

Superfamily: Phthiracaroidea Perty, 1841

Family: Phthiracaridae Perty, 1841

Genus: *Hoplophorella* Berlese, 1923

Subgenus: *Hoplophorella (Hoplophorella)* Berlese, 1923

Generic Diagnosis

Members are characterized by 15 pairs of notogastral setae, 9 pairs of genital setae, 5 pairs of ano-adanal setae, 3 pairs of median anal (an_1-an_3) inserted adjacently on inner margin of anoadanal plates and 2 pairs of lateral setae (ad_1 & ad_2).

***Hoplophorella (Hoplophorella) vitrina* (Berlese, 1913)**

(Plate- 23, Figs.1-3)

Color: Pale Yellow

Measurements:

Length of Aspis: 225- 255 μm

Width of Aspis: 105 – 120 μm

Length of Notogaster: 465- 480 μm

Width of Notogaster: 255- 315 μm

Dorsal Region (Fig. 1)

Prodorsum

Prodorsum with 2 pairs of lateral carinae, one on each side of the prodorsum; aspis almost triangular with a blunt rostral apex; seta *ro* thick and slightly curved inwards and inserted slightly away from the rostral apex,

phylliform, lanceolate and smooth with well discernible midrib; seta *le* the longest among the prodorsal hairs; seta *in* small, smooth and spine like and inserted inner to seta *le*; seta *ex* minute and placed posterior to *bo*; comparative lengths of the prodorsal hairs follows the order $le > ro > in > ex$; sensillus elongate, phylliform with distinct midrib, directed forward, the head portion excepting the midrib appears hyaline; the median surface of prodorsum punctated and posterior surface with varying number of vertical striations (Fig.1a).

Notogaster

Notogaster slightly convex, integument sculptured with micropunctations intermingled with round foveoles, more prominent at dorsal aspect, but feeble, sparsely arranged on medio- lateral regions; notogaster bears 15 pairs of foliate setae with distinct midrib and clear hyaline boundary and of varying size, the midrib, under higher magnification seems to possess fine ramifications, seta d_1 the longest and e_2 the shortest.

Ventral Region

Rutellum broad and stout with 3 well developed notches, the central notch smaller than the lateral ones; length of infracapitular setae varies in the order $h < m < a$; chelicerae stout and punctate; epimeral setal formula 1-0-1-1, all setae smooth and pointed; each genital plate rectangular in outline, ornamented with foveoles and carries 4 pairs of smooth, thin setae along the inner margin inserted equidistantly (Fig.2); each broad and short aggenital plate carries one minute seta ag_1 ; ano-adanal plates rectangular and short,

resembling the genital plate, each ano- adanal plate carries 3 anal and 2 adanal setae along the median border, seta ad_1 resembles the notogastral setae while seta ad_2 resembles the anal setae, smooth and thin (Fig.3).

Legs

Legs monodactylous with a thick empodial claw on each tarsal segment.

Materials examined

1♂ and 2♀♀ recovered from the soil samples collected from the mangrove areas of Thalassery, (11°75'55.94"N 75 °49'13.81E) Kannur (Dt.) of North Kerala on 16.05.2011, coll. P.K. Syamjith.

Remarks

The genus *Hoplophorella* erected by Berlese (1923). The present specimen on comparison with 90 known species of the subgenus shows very close resemblance to the species *Hoplophorella (H.) vitrina* (Berlese, 1913) in the external features and in the nature and arrangement of prodorsal, notogastral, genital, anal and adanal setae.

Infraorder: Holosomata Grandjean, 1969

Superfamily: Crotonioidea Thorell, 1876

Family: Trhypochthoniidae Willmann, 1931

Genus: *Afronothrus* Wallwork, 1961

Generic Diagnosis

4 pairs of genital setae; aggenital setae absent; sensilli short; notogaster with 15 pairs of setae, the posterior ones being much longer than anterior;

fissure *ip* large and transverse; 2 pairs of adanal hairs, anal hairs lacking or virtual (1 pair); tarsi tridactyl.

***Afronothrus arboreus* Ramani & Haq, 1992**

(Plate -24, Figs.1-2)

Colour : Transparent to pale brown

Measurements : Length: 525µm (515-540 µm)

Width: 285 µm (285-300 µm)

Dorsal Region (Fig. 1)

Prodorsum

Prodorsum triangular and gradually broadening downwards with lateral excrescence on either side of the bothridia; rostrum round, blunt and without any incisions; seta *ro* inserted at the rostral apex, narrow, tapering, flexible and roughened; a pair of lateral ridges present on either side of the prodorsum in between seta *ro* and bothridia, with thickened anterior halves; lamella absent; seta *le* stiff, erect, roughened, longer than their mutual distance; seta *in* longest among the prodorsal setae, inserted very near to *bo*; each bothridium with a circular opening; *ss* short stalked with a spherical, smooth head projecting laterad; seta *ex* absent; integument of the prodorsum distinctly porose.

Notogaster

Notogaster more or less oval with a slightly wavy dorsosejugal suture; notogaster with 15 pairs of setae of varying size, setae c_1 , c_2 and c_3 of equal length, seta d_2 very small and h_2 and ps_2 very long, equal in size and tapering terminally, f_2 and ps_2 roughened, insertions of setae f_2 and h_3 visible ventrally, h_1 thick, heavily barbed and with prominent insertion point, h_2 and h_3 oppose each other in direction, ps_1 and ps_2 with prominent insertion points, ps_3 located ventrally; a transverse furrow with 2 or 3 distal branches present in between dorsosejugal suture and above the level of setae c_2 and c_3 ; another well developed transverse furrow present between the insertions of cp and d_1 anteriorly and e_1 and e_2 posteriorly, which merges with the polygonal reticulations on present on the lateral sides of the notogaster; fissure ia placed obliquely, below the insertion of c_3 ; im located similarly in the median furrow; ip resembles im but longer, located near to seta h_1 ; lateroabdominal gland (gla) located below the middle of the notogaster; posterior and posterolateral margins of the notogaster more strongly chitinized than the mid dorsal regions; notogastral integument ornamented with polygonal reticulations from posterior to the median furrow.

Ventral Region (Fig. 2)

Labiogenal articulation diarthric type; mentum broad and porose in nature; rutellum broad, non- sclerotized and with 3-4 notches; infracapitulum with smooth setae *a*, *m* and *h*, *a* longest, *m* shortest and *h* of intermediate length; epimeral boundaries clearly separated and all setae smooth and of varying size; epimeral setal formula 3-1-3-2; setae *1b* and *3b* long, *1a*, *2a* and *4c* very short and *1c*, *3a*, *3c* and *4b* intermediate in size; genital and anal plates contiguous, the former being broader anteriorly and narrow posteriorly, 4 pairs of smooth genital setae ($g_1 - g_4$) arranged close to the inner margin of the genital plates, setae g_1 and g_2 inserted anteriorly, one behind the other, g_3 placed slightly middle of the plate and g_4 located posteriorly; seta *ag* absent; anal plate narrow, each plate carrying a single smooth seta; 2 pairs of smooth adanal setae (ad_1 and ad_2) present; lyrifissure *iad* located slightly above the level of fissures *ian* and *ips* and above the level of fissure *iad*; *ih* seen far above, lateral to the genital plates.

Legs

All legs tridactylous and homodactylous, chaetotaxy of leg I: 1-6-4-7-8; all leg segments except the trochanter bear large round foveoles irregularly on all segments except trochanter.

Materials examined

2♀♀ collected from the tidal debris left after high tide at Kadalundi – Vallikkunnu Community reserve, Kozhikode (Dt.), Kerala, India on 13.08.2014 coll. P K. Syamjith.

Remarks

The genus *Afronothrus* was erected by Wallwork (1961) with *A. incisivus* as the type species from Ghana. Presently the genus includes only 2 valid species including the type species. The specimen examined during the current study shows close resemblance to the second valid species under the genus viz. *A. arboreus*, an arboreal species described by Ramani and Haq, 1992 recovered from the coconut palm foliage at the Calicut University Campus, Kerala, South India in the nature of setae, *ro*, *le*, *f*₂ and *ps*₂, absence of lamellae, clearly spherical nature of sensillus, thick and densely barbed nature of seta *h*₁ and the stiff nature of setae *h*₃ and absence of polygonal reticulations on the ventral plate. This forms the second report of the species from Kerala and is the first information on the occurrence of the species in the mangrove ecosystems.

Superfamily: Nothroidea, Grandjean, 1954

Family: Trhypochthoniidae, Willmann, 1931

Genus: *Archegozetes*, Grandjean, 1931

Generic Diagnosis

Bothridium present; rostral setae removed from each other; members possess 7 pairs of genital setae, 2 pairs of adanal setae and monodactylous legs.

***Archegozetes longisetosus* Aoki, 1965**

(Plate- 25, Figs.1-2)

Colour	: Yellowish Brown
Measurements	: Length: 760-790 μm
	Width : 522-568 μm

Dorsal Region (Fig. 1)

Body narrow anteriorly and broad posteriorly; integument appears densely punctate, soft, weakly sclerotized.

Prodorsum

The anterior end of the prodorsum pointed; 3 pairs of barbed prodorsal setae present; seta *ro* setiform, inserted far below the rostral tip; setae *le* and *in* moderately flagellate; *bo* bell shaped; *ss* long, flagellate with small barbs; scattered groups of area porosae located at the interlamellar area, in between setae *in*.

Notogaster

Notogaster more or less oval in outline, the actual size determined by presence or absence of eggs within the viscera; 15 pairs of ciliated, barbed setae of varying size present, all heavily barbed distally and lesser at proximal ends; laterally, lateroabdominal gland (*gla*) present at the region of setae e_2 , f_2 and h_2 as a dark brown spot, the glandular opening seen very close to the insertion point of f_2 ; notogastral fissures *ia*, *im*, *ip* and *ih* clearly visible, *ia* located near c_3 , *im* between d_3 and e_2 and *ip* near seta h_2 .

Ventral Region (Fig.2)

Infracapitular setae 3 pairs, anterior *a* and posterior *h* setae longer than the smooth *m* seta; epimeral region separated from the infracapitulum by a transverse sub-mental plate (*spm*); anterior region of which lined by the entire mentotectum; epimeres I and II separated from epimere III by a sejugal furrow, epimeral setal formula 3-1-3-3; 7 pairs of ciliated genital setae present, anterior 4 pairs (*g*₁-*g*₄) inserted very close together at the anterior half of the genital plate and the posterior 3 pairs (*g*₅-*g*₇) aligned more widely; each anal plates carries 2 short barbed setae; adanal plates with 3 pairs of barbed setae, length of which decreases from *ad*₁-*ad*₃; lyrifissures *ian* and *ips* located on the ventral plate.

Legs

All legs monodactylous.

Materials examined

2♀♀ recovered from the litter samples collected from the mangrove ecosystems at Thalassery (11°45'18.12"N 75°29'30.58"E), Kannur (Dt.) on 16.01.2013, North Kerala, India, coll. P.K. Syamjith.

Remarks

The present specimen very closely resemble *A.longisetosus* described by Aoki (1965) from Japan in the nature and arrangement of prodorsal hairs, possession of 15 pairs of notogastral setae, 7 pairs of genital setae, nature of sensillus etc. and hence was assigned to the same species. This forms the new

report of the species in the mangrove ecosystems of India, especially from Kerala.

Infraorder: Desmonomata

Superfamily: Carabodoidea Koch, 1837

Family: Carabodidae Koch, 1837

Genus: *Carabodes* Koch, 1835

Subgenus: *Carabodes (Klapperiches)* Mahunka, 1979

Generic Diagnosis

Members possess 4 pairs of genital and 10 pairs of spatuliform notogastral setae; distance between genital and anal plates shorter than the length of genital plates; epimeral setal formula 1-1-3-3; seta ad_1 post-anal, ad_2 and ad_3 in para-anal position.

***Carabodes (Klapperiches) penicillus* (Mahunka, 1998)**

(Plate 26, Figs.1-3)

Colour : Yellowish Brown

Measurements : Length: 360 μm (330-376 μm)

Width: 165 μm (150-180 μm)

Dorsal Region (Fig.1)

Prodorsum

Rostrum broadly rounded, lamellae narrow, running marginally, broad, lamellar setae simple, arched mediad, seta *ro* thin and *in* penicillate; lamellar

surface smooth, seta *le* thin, simple, inserted at the lamellar tip; interlamellar region postulate distinctly; *ss* moderately long, directed outwards, capitulum calyciform, open laterally.

Notogaster

Dorsosejugal suture straight, entire surface tuberculate; 10 pairs of small stumpy, penicillate notogastral setae present; lyrifissures *im* and gland *gla* in typical lateral position.

Ventral Region (Fig.2)

Infracapitulum diarthric type, infracapitular setae 3 pairs; mentum and coxisternal region foveolate medially and laterally; ventral plate ornamented with tubercles; epimeral region relatively larger than the ano-genital area, thereby genital and anal openings appearing on the posterior half of the body, near the anal opening; epimeral setae minute, epimeral setal formula 1-1-3-3; 4 pairs of genital, 1 pair of aggenital, 2 pairs of anal setae, seta *ag* thickened and ciliate, located near the postero-lateral border of the genital plates; setae *ad*₁ penicillate, like notogastral setae.

Legs

All legs monodactylous with a single, strong sickle- shaped claw, foveoles on abaxial surfaces of femora I-IV (Fig.3).

Materials examined

3♂♂ and 6♀♀ recovered from the tidal debris left after high tide at the mangrove ecosystems of Kadalundi- Vallikkunnu community reserve (11°7'38.43"N 75°49'54.55"E) Kozhikode (Dt) on 13.08.2014 and 1♂ and 3♀♀ from the mangrove litters of Ezhome (12°02'57.54"N 75°27'71.60"E), Kannur (Dt) on 16.01.2013, North Kerala, India, coll. P.K. Syamjith.

Remarks

The present species of *Carabodes* collected from the Kadalundi Vallikkunnu community reserve shows very close resemblance to *K. penicillus* (Mahunka, 1998) described from St. Lucia (Antilles) Island in the possession of 10 pairs of penicillate notogastral setae, nature of pustules on notogaster and in the shape of sensillus. It is the first report from the mangrove ecosystems of India, especially from Kerala.

Superfamily: Ameronothroidea Willmann, 1931

Family: Selenoribatidae Schuster, 1963

Genus: *Selenoribates* Strenzke, 1961

Generic Diagnosis

Small sized intertidal mites; cerotegument granular; short or minute interlamellar setae; lamellar ridges present but short; sensillus flagelliform and long; pedotectum I small but robust, pedotectum II absent; 14 pairs of

notogastral setae; obvious depressions on anterior part of notogaster; epimeral setal formula 1-0-1-1; genital plates with 3-4 pairs of setae; aggenital setae absent; 2- 3 pairs of adanal setae; 1-3 pairs of anal setae; legs monodactylous, claws with one or 2 proximoventral teeth.

***Selenoribates mangrovius* sp.nov.**

(Plate -27, Figs.1-3a)

Colour	: Dark brown
Measurements	: Length: 278 μ m (278-308 μ m) Width: 163 μ m (163-178 μ m)

Dorsal Region (Fig. 1)

Prodorsum

Rostrum rounded, rostral apex with cerotegument; seta *ro* short; prodorsal ridge/ lamellar ridge present; setae *le* and *in* very short and simple; seta *ex* minute; lamellar ridges short, not reaching insertion point of seta *in*; bothridial cup large; *ss* flagelliform and long (53 μ m) (Fig.1a); tutorium small but weakly developed; prodorsal surface with granular cerotegument .

Notogaster

Notogaster rounded in dorsal view, concave in lateral view; anterior notogastral margin complete; notogaster lacks any horn- like projections at the anterior border; 3 notogastral depressions on anterior part of notogaster,

its longitudinal ridges reaching above setae *la* and *da*; 14 pairs of notogastral setae present, all smooth except *da*- *dp*, the latter two slightly serrate; 5 pairs of lyrifissures present, *ia* posterior to *c*₂; lateral abdominal gland opening (*gla*) located next to seta *la*; posterior margin of notogaster densely covered by thick cerotegument.

Ventral Region (Fig. 2)

Labiogenal articulation diarthric type; infracapitulum with setae *a*, *m* and *h*; all setae simple, long and smooth; epimeral setal formula 1-0-1-1, all setae smooth, seta *1b* long, reaching trochanter III, setae *3b* and *4a* short; pedotectum I small, but well developed, pedotectum II absent; discidium developed as a conical ridge between acetabula III and IV; a granulated small, sternal cavity present on epimere I and level of apodeme III; a dark coloured insertion of tendon β located adjacent to anterior corners of genital opening; genital plates with 3 pairs of setae, 2 pairs arranged longitudinally at anterior region and 1 pair at the posterior margin; aggenital seta absent; anal plates triangular bearing 2 pairs of simple setae, inserted at the anterior and posterior regions of anal plates; 3 pairs of short and simple adanal setae (*ad*₁ – *ad*₃), present; lyrifissure *iad* in paranal position, obliquely arranged, adjacent to anterior corners of anal plates.

Legs

All legs monodactylous, all tarsi with a hook- like claw bearing a prominent proximoventral tooth and a minute proximodorsal tooth (Fig.3a);

all femora possess ventral carinae; chaetotaxy of leg I (Fig.3) : 0-3-2(1)-3(2)-17(2) tibia I with long solenidion ϕ_1 .

Materials examined

Holotype ♀; paratypes: 4♂♂ and 5♀♀ from the mangrove litter samples at Ezhome of North Kerala on 08.10.2013, coll. P.K. Syamjith.

Type repository

The type specimen will be deposited at the Zoological Survey of India (ZSI) Calicut, Kerala, India.

Remarks

The genus *Selenoribates* was erected by Strenzke (1961) based on the type species *S.foveiventris*. This genus comprises littoral oribatids with marine- associated habitats, especially those from the intertidal and coastal regions. At present, the genus includes 10 valid species described from various countries viz. *S.foveiventris* Strenkze, 1961; *S.mediterraneus* Grandjean, 1966; *S.ghardaquensis* Abdel-Hamid, 1973; *S.elegans* Pfingstl, 2013; *S.quasimodo* Pfingstl, 2013; *S.satanicus* Pfingstl, 2013; *S.arotroventer* Pfingstl, 2015; *S.asmodaeus* Pfingstl, 2015; *S.niccus* Pfingstl, 2015 and *S.divergens* Pfingstl, 2015. The present new species, *S. mangrovius* can be distinguished from the known species like *S.divergens*, *S.asmodaeus* and *S.arotroventer* described from the coasts of the Red Sea and Indo- Pacific

region by the possession of flagelliform sensillus, simple notogastral setae, short prodorsal ridges and oblique disposition of *iad*. The large size of the species (278-308/163-178 μ m) easily differentiates it from *S.ghardaqensis* (198-218/119-139 μ m) along with the possession of other features like presence of 3 pairs of genital and adanal setae as well as 2 pairs of anal setae. Presence of 14 pairs of simple notogastral setae of the new species easily differentiates it from *S. arotroventer* and *S. niccus* (15 pairs of branched setae in both). The possession of 3 pairs of adanal setae and a single dorsal tooth on leg claws clearly distinguishes the new species from *S. mediteraneus* and *S. foveiventris* (2 pairs of adanal setae and toothless condition of leg claw in both). Larger size of the body, possession of 3 pairs of adanal setae and a single ventral tooth on leg claws separate the new species from *S.elegans* (200-203; 108/122 μ m). Possession of the following character combination detected in the new species clearly separates it from all the known species and assign it as a new taxon under the genus:

1. Larger body size (278-308 / 163-178 μ m)
2. Complete nature of dorsosejugal suture
3. Presence of short lamellar ridge
4. Absence of strongly projecting horn-like structures at the anterior border of notogaster

5. Presence of 2 pairs of anal setae
6. Presence of a single dorsal and ventral tooth each on leg claws.

Etymology

The specific name derived from the nature of habitat of the species namely the mangrove ecosystem of North Kerala, India.

DESCRIPTION OF NEW GENUS

Superfamily: Ameronothroidea Willmann, 1931

Family: Fortuyniidae Hammen, 1963

Genus: *Holocarinozetes* gen. nov.

Type species: *Holocarinozetes epimeratus* gen.nov. sp.nov.

Diagnosis: Small sized (274-300 μm in length), dark brown coloured, highly sclerotized intertidal mites; cerotegument thin and granular; tutorium present; interlamellar setae short and conspicuous; lamellar ridges demarcating rostrum; sensillus clavate, spinose apically; notogaster with 15 pairs of setae; lenticulus present; van der Hammen's organ with specific cuticular channels; a pair of strongly projecting longitudinal carinae running along the entire lateral borders of epimeres I to IV; epimeral setation 3-1-2-2; genital setae 4 pairs; aggenital setae 1 pair, anal setae 2 pairs and adanal setae 3 pairs; all legs monodactylous with hook-like claws.

Generic Diagnosis

Dark brown coloured intertidal mites; mean length 300µm, mean width 195µm; lamellar ridges conspicuous and long, extending up to end of prodorsum; cuticle of notogaster showing specific obvious tuberculated pattern; 15 pairs of very short and blunt notogastral setae; on ventral side, a characteristic pair of ventral carinae running longitudinally from epimeres I to IV; genital plates with 4 pairs of setae.

H. epimeratus gen.nov.sp.nov.

(Plate- 28, Figs.1-2b; Plate- 29, Figs.1, 2A-D; Plate- 30, Figs.1-6)

Colour : Dark brown

Measurements : Length: 300 (276-300µm)

Width : 195 (180-195µm)

Dorsal Region (Plate-28, Fig.1; Plate-30, Figs.1-3)

Integument: Colour dark brown, cuticle of notogaster with irregular depressions forming a tuberculated pattern (Plate-28, Fig.1b; Plate- 30, Fig.5) cerotegument thin and granular.

Prodorsum:

Rostrum rounded in dorsal view, clearly separated from the prodorsum by a narrow ridge, seta *ro* simple; lamellar ridges conspicuous and long, lamellar surface ornamented with small granules; seta *le* very short and

inconspicuous; seta *in* 15-18 μ m long, thin and smooth; a single pair of minute exobothridial setae (*ex*) present on either lateral sides; bothridia small, cuticular bothridial cups opened laterally; sensillus with smooth stem, capitulum clavate and barbed/spinose apically, as shown in (Plate-28,1a; Plate-30, Fig.1a)

Notogaster

Rounded in dorsal view, convex in lateral view; dorsosejugal suture complete and arched; lenticulus appears as a median rectangular light spot, near to anterior margin of notogaster (Plate-30, Fig.1); integument of notogaster with small, irregular circular depressions, forming tuberculated pattern (Plate-30, Fig.5); 2 pairs of convex parallel ridges (hump like projections) run along the entire length of notogaster on either side (Plate-30, Fig.1); entire surface of the notogaster including the ridges tuberculated (Plate-30, Fig.1&2); 15 pairs of bristle like setae, *c*₁₋₃, *da*, *dm*, *dp*, *la*, *lm*, *lp*, *h*₁₋₃, *p*₁₋₃ and 5 pairs of lyrifissures arranged on notogaster as shown in (Plate-29, Fig.1).

Lateral Region (Plate- 29, Fig.1; Plate- 30, Fig.2)

Cerotegument finely granular; tutorium present; pedotectum I weakly developed, pedotectum II represented by a plate- like ridge; Van der Hammen's organ modified, consisting of three combined parts, first major canal connected outside by a small slit, starting at the lateral part of

dorsosejugal suture and reaching posterior of bothridium and running ventral to the area between acetabula II and III, second and third canals start near the bothridial opening and diverge towards the acetabula III and IV respectively (Plate-30, Figs. 2&4)

Ventral Region (Plate- 28, fig.2; Plate- 30, Fig. 6)

Infracapitulum diarthric type with 3pairs of setae (*h,m,a*); epimeral setation 3-1-2-2, setae 1*b* and 3*b* about twice longer than the remaining setae; a characteristic pair of ventral carinae run longitudinally from epimeres I to IV (Plate-30, Fig. 6) which diverge laterally beyond leg IV; epimeral surface tuberculated; genital plates broader anteriorly, each plate bears 4 smooth setae, seta *g*₁ minute, located at anteriormost margin of the genital plate, *g*₂ & *g*₄ located paraxially, *g*₃ arranged at lateral margins of the genital plates; and ano-genital openings located adjacently, both surrounded by strongly sclerotized cuticle; two obvious points of black pigmentation, representing insertion of tendon “*β*” (Grandjean 1966) adjacent to corners of genital orifice; one pair of simple aggenital setae, located laterad of ano-genital plates; 2 pairs of short and simple anal setae, arranged in a longitudinal row; 3 pairs of simple adanal setae (*ad*₁₋₃) located; adanal fissure *iad* obliquely placed between *ad*₂ and *ad*₃ nearer to the former.

Legs (Plate- 29, Fig.2A-D)

All legs monodactylous with long hook like smooth claws without proximoventral tooth; all segments heavily sclerotized; femur I with a strong ventral carina and granulated cuticle; on tarsus-I with long solenidion (φ_1) long and slender while φ_2 short and slender, famulus (ε) placed near to ω_2 ; chetotaxy of leg I: 0-4-2(1)-2(2)-18(3); II: 3-1(1)-2(1)-17(1), solenidion ω_2 short and slender; III: 2-1(1)-3(1)-17(0); IV: 2-2-3(1)-14(0).

Etymology

The generic name and species epithet of the new taxon are derived from the presence of 2 conspicuous longitudinal carinae running along the entire length of the epimeral plates from epimere I-IV.

Remarks

The family Fortuyniidae was erected by Van der Hammen (1963) based on the type genus *Fortuynia* and with the type species, *F. yunkeri*. The family of Fortuyniidae represents a thalassobiontic group and presently it comprises 3 genera viz. *Alismobates* Luxton 1992, *Circellobates* Luxton, 1992 and *Fortuynia*. Members of this family are distributed transoceanically and dwell in intertidal habitats of tropical and subtropical coasts. A comparison of the characters present in the specimen collected during the

current study enabled to erect another new genus viz. *Holocarinozetes* under the family Fortuyniidae based on characters like,

1. Presence of Van der Hammen's organ
2. Presence of lenticulus
3. Similarities in the setation of genital, anal and adanal regions.

However, the possession of the following character combinations clearly demarcates the present specimens from the members of all the previously described genera and to assign them to a new genus viz. *Holocarinozetes* under the family Fortuyniidae.

The new genus keeps its identity separate from all the congeners of the family based on the following unique features:

1. Possession of a pair of distinct ventral carinae running along the entire length of epimeral area (epimeres I to IV)
2. Presence of 2 pairs of conspicuous convex, hump-like parallel ridges on notogaster.
3. Presence of distinct interlamellar ridges
4. Possession of 15 pairs of bristle like setiform setae.
5. Small size of the body (250-300)µm

Materials examined

Holotype ♀; Paratypes: 5♀♀ and 9♂♂ from the intertidal mangrove ecosystem at Kadalundi (11° 7'54.89"N 75°49'44.55"E), upper eulittoral zone (leaf litter of *A. marina* and *A. ilicifolius*) on 24.02.2011. coll. P.K. Syamjith.

Type repository

The type specimen will be deposited at the Zoological Survey of India (ZSI) Calicut, Kerala, India.

Key to the known and new of genera of Fortuyniidae

1. Sensillar capituli smooth and membranous; genital plates with 5 pairs of setae ***Fortuynia* van der Hammen, 1960**
- Sensillar capituli conspicuously barbed; genital plates with 4 pairs of setae2
- 2 (1). Hysterosoma oval in shape; epimeron 3 pierced with 2 conspicuous, annulated pores ***Circellobates* Luxton, 1992**
- Hysterosoma globular in shape; epimeron 3 not pierced with annulated pores.....3
- 3 (2) No characteristic pair of ventral carinae on epimeral area; no convex, hump- like projections on notogaster; 14 pairs of notogastral setae ..
..... ***Alismobates*, Luxton, 1992**

A Characteristic pair of ventral carinae running longitudinally from epimere I to IV; presence of 2 pairs of conspicuous convex, hump-like parallel ridges on the notogaster; 15 pairs of notogastral setae.....*Holocarinozetes* gen.nov.

Superfamily: Limnozetoidea Thor, 1937

Family: Austrachipteriidae Luxton, 1985

Genus: *Lamellobates* Hammer, 1958.

Subgenus: *Lamellobates (Lamellobates)* Hammer, 1958

Generic Diagnosis

The members possess broad, plate like and closely situated lamellae and the anterior borders of which are without free tips; the interlamellar area small; presence of 2 pairs of anal and 2 pairs of adanal setae.

***Lamellobates (Lamellobates) molecula* (Berlese, 1916)**

(Plate-31, Figs. 1-2)

Color : Light brown

Measurement : Length: 280- 305 µm

Width : 190 – 206µm

Dorsal Region (Fig.1)

Prodorsum

Rostrum broadly pointed; seta *ro* very long, reaching far beyond the tip of the rostrum, unilaterally feathered; lamellae broad and plate like, the

median sides of which stiffened by a chitinous thickening, ending posteriorly in a median knob in between, lamellae lack distal tips, slightly asymmetrical, left inner cuspides completely rounded, the right one with a short, sharp apex, both outer cuspis comparatively short, narrow and sharply pointed; seta *le* thick and well barbed; seta *in* setiform, long, reaching the tip of *le*; *ss* with a slender stalk and clubbed, barbed head.

Notogaster

Notogaster broadest slightly below the middle; anterior border marked by a highly convex dorsosejugal suture; 9 pairs, thin, long, setae bearing small barbs inserted on the notogaster, seta *p*₃ absent; fissure *ia* located on pteromorph, *im* medially and *ip* aligned posteriorly.

Ventral Region (Fig. 2)

Infracapitulum with 3 pairs of setae *a*, *m* and *h*, all simple; epimeral setae short and smooth; epimeral setal formula 3-1-2-2; 6 pairs of genital setae, *g*₁ - *g*₃ located at the anterior margins of the genital plate, *g*₃ - *g*₆ located laterally; aggenital seta (*ag*) inserted posterolateral to the genital plate; 2 pairs of anal setae present of which *an*₁ inserted posteriorly, and *an*₂ anteriorly; 2 pairs of adanal setae (*ad*₁ and *ad*₂) situated para-anally; fissure *iad* closely apposed to antero-lateral corner of each anal plate.

Leg

All legs monodactylous.

Materials examined

11 ♀♀ collected from a mangrove ecosystem at Pazhayangadi, Kannur (Dt.), Kerala, India on 25. 05. 2012. coll. P.K .Syamjith.

Remarks

The present species of *Lamellobates* collected from a mangrove forest of Pazhayangadi, Kannur (Dt.) of North Kerala shows very close similarities with *Lamellobates (L.) molecula* described by Berlese (1916) in the presence of broad, asymmetrical lamellar plates and the nature and arrangement of 9 pairs of notogastral hairs and the ventral features.

Superfamily: Limnozetoidea Thor, 1937

Family: Austrachipteriidae Luxton, 1985

Genus: *Lamellobates* Hammer, 1958

Subgenus: *Lamellobates (Paralamellobates)* Bhaduri & Raychaudhuri, 1968

***Lamellobates (Paralamellobates) bengalensis* Bhaduri & Raychaudhuri, 1968**

(Plate-32, Figs.1-2)

Color : Light brown

Measurement : Length: 245-290µm

Width: 176-192µm

Dorsal Region (Fig.1)

Rostrum pointed with slightly concave sides, seta *ro* unilaterally barbed; lamellae broad, plate like with free anterior tips, outer tips being longer than the inner ones; seta *le* stout and roughened; seta *in* long and barbed; *ss* projects forward, bearing short spines on the head; dorsosejugal suture convex; notogaster with 9 pairs of simple setae; fissures *ia*, *im* and *ip* present on the notogaster.

Ventral Region (Fig. 2)

Labio-genal articulation diarthric type; mentum broad and somewhat rectangular; setae *h* and *m* smooth and almost equal in size. seta *a* smooth but shorter; epimeral setal formula 3-1-2-2, all setae smooth; genital plates broad anteriorly, bearing 6 pairs of smooth setae; aggenital setae (*ag*) smooth; anal plates carry a single pair of smooth setae; 2 pairs of adanal setae detected, fissure *iad* placed at the anterolateral corner of the genital plate.

Leg

All legs monodactylous.

Materials examined

2♂♂ and 3 ♀♀ collected from a mangrove ecosystem at Olipram kadavu, 11° 7'41.40"N 75°51'50.72"E (Dt.), Kerala, India on 25. 05. 2012. coll. P.K .Syamjith.

Remarks

The present specimen closely resembles *L. (P.) bengalensis* erected by Bhaduri & Raychaudhuri, 1968 from West Bengal, India in the general morphology including the presence of broad lamellar plates, nature and arrangement of prodorsal, notogastral and ventral setae.

Superfamily: Oripodoidea Jacot, 1925

Family: Oribatulidae Thor, 1929

Genus: *Phauloppia* Berlese, 1908

Generic characters

Lamella indistinct; lamellar seta situated closer to interlamellar setae than to rostral setae; sensillus short and clubbed; 14 pairs of notogastral setae present; genital plates with 4 pairs of setae.

***Phauloppia kadalundiensis* sp.nov.**

(Plate- 33, Figs.1-4)

Colour	: Reddish Brown
Measurements	: Length: 384 µm (380-390 µm)
	Width: 256 µm (250-275 µm)

Dorsal Region (Fig. 1)**Prodorsum**

Broad, all prodorsal setae long and distinctly barbed; seta *ro* long, barbed, measuring 51µm in length and inclined inwards; lamella indistinct

(faint), seta *le* erect and somewhat thicker, smaller than *ro* and measures 40µm in length; seta *in* very long (114µm), roughened, inserted close to anterior notogastral margin; the integument of the dorsal surface near *bo* and *in* roughened by transverse wrinkling; seta *ex* fine, barbed and measures 14 µm in length, area near seta *ex* contains numerous microtuberculated projections; *ss* capitulate with granulated head; a pair of area porosae (*Aj*) located behind the insertion point of setae *in*.

Notogaster

Anterior border of notogaster slightly convex; 14 pairs of notogastral setae present, all setae very fine, almost smooth, slightly barbed and of varying in size (11-15µm) and shape as figured; setae *c*₁ and *c*₂ located close together; 5 pairs of oval to round area porosae present, *Aa* the largest, *A*₁ located far away from *Aa*, *A*₄ small, situated just near to the insertion point of seta *h*₁; lyrifissure *im* long, situated in between *dm* and *lm*; *ip*, *ih*, *ips* clearly visible; lateral abdominal gland (*gla*) well developed; surface of notogaster not evenly smooth, but scattered with small granules (at 40x magnification).

Ventral Region (Fig. 2)

Infracapitulum possesses 3 pairs of simple setae *a*, *m* and *h*, seta *h* long reaching nearer to seta *a*; epimeral setal formula : 3-1-3-3, setae small and setiform, *4a*, *4b* and *4c* longer, setae *1c*, *3c* and *4c* located laterally;

genital plates pentagonal in shape, as long as wide, carrying 4 pairs of small, smooth, and setiform setae; 1 pair of aggenital, 2 pairs of anal and 3 pairs of adanal setae present; adanal fissure (*iad*) arranged obliquely, close to anal margin.

Legs

All legs hetero- tridactylous; chaetotaxy of leg I(Fig. 4): 0-4-3(1)-4(2)-19 (2), trochanter- I bears one barbed seta; femur-I carries 4 setae, genu-I carries 3 setae including 1 solenidion, σ ; tibia –I bears 6 setae including 2 solenidia φ_1 and φ_2 , tarsus –I bears 19 setae including 2 solenidia ω_1 and ω_2 and a famulus ε .

Etymology

The specific epithet of the new taxon is derived from the name of the type locality i.e. the Kadalundi- Vallikkunnu community reserve.

Materials examined

Holotype ♀; paratypes : 2♂♂ and 3♀♀ recovered from the dead twigs and leaves of *A. marina* from the Kadalundi- Vallikkunnu community reserve mangrove (11° 7'54.89"N and 75°49'44.55"E), Calicut (Dt) of North Kerala on 17.11.2011, coll. P.K. Syamjith.

Type repository

The type specimen will be deposited at the Zoological Survey of India (ZSI) Calicut, Kerala, India.

Remarks

Berlese (1908) erected the genus *Phauloppia* with *Oppia conformis* as the type species. As per the most recent Oribatid catalogue (Subias, 2015), 25 species have been enlisted under the genus, of which 4 species are listed as “sp. inq.” and hence excluded from the comparison made during the present study. On comparison with the remaining 21 valid species, the present species resembles the other known species of the genus in the shape and size of the body as well as the nature of the sensillus. However, the presence of 5 pairs of area porosae in the new species helps to distinguish it from all the known species of the genus with the exception of *P. adjecta* which possesses 5 pairs of area porosae. Possession of 14 pairs of notogastral setae of the present species clearly separates it from known species like *P. tuberosa* Fujikawa, 1972 and *P. incompta* Pérez-Íñigo & Peña, 1996 (both possess 13 pairs of notogastral setae each). The new species resembles *P. adjecta* described by Aoki and Ohkubo (1974) in sharing characters like 5 pairs of area porosae, 14 pairs of notogastral setae, 4 pairs of genital, 2 pairs of anal and 3 pairs of adanal setae. However, the following character deviations observed in the

present species clearly segregate it from *P. adjecta* and erect it as a new species under the genus *Phauloppia*.

1. Presence of 5 pairs of intact, oval shaped area porosae on the notogaster, in which *Aa* not divided unlike *P. adjecta* in which the *Aa* divided in to *Aa*₁ & *Aa*₂.
2. Barbed nature of prodorsal setae.
3. Presence of transversely arranged wrinkles on the integument at the interlamellar area.
4. Seta *in* being extremely long.
5. Presence of 14 pairs of short, setiform setae on notogaster unlike the long, flagelliform setae of *P. adjecta*.
6. Presence of numerous microtuberculated projections at the exobothridial surface.

Superfamily: Oripodoidea Jacot, 1925

Family: Hemileiidae J. & P. Balogh, 1984

Genus: *Siculobata* Grandjean, 1953

Subgenus: *Siculobata (Siculobata)* Grandjean, 1953

Generic Diagnosis

Anterior border of notogaster straight; pteromorphae absent; notogaster with 4 pairs of sacculi and 10 pairs of setae; sensilli short, capituli usually

capitate; with or without aggenital setae (1 pair if present); genital plates with 4 pairs of setae; 2 pairs of anal setae; 3 pairs of adanal setae; tarsi I-III short; solenidia of tibiae III and IV ending in a small round vesicle, tridactylous, median claw somewhat stouter than others.

***Siculobata (Siculobata) malabarica* Ramani & Haq, 1998**

(Plate 34, Figs.1-3b)

Colour : Light to dark Brown

Measurements : Length: 370 μm (330-375 μm)

Width: 240 μm (220-275 μm)

Dorsal Region (Fig.1)

Prodorsum

Rostrum rounded, ending in a pointed tip and with 2 incisions; seta *ro* long, barbed, thin, sharply pointed and directed anteriorad; lamella sheath-like originate from the base of bothridium, seta *le* inserted at the tip of the lamella, somewhat thicker than *ro*, bearing short spines and ending in a blunt tip; *ro* and *le* connected by prolamellar ridge; seta *in* longest, outwardly directed and situated far behind *le*; a pair of area porosae (*Al*) situated either side of the lamellae and exterior to them, almost at the level of *in*; seta *ex* absent; sensilli and bothridia almost covered by anterior notogastral border. sensillus (*ss*) club- shaped with a short stalk, roughened capituli; small punctations located on the prodorsal surface, near and exterior to the lamella.

Notogaster

Spherical and broadest medially; anterior border demarcated from the prodorsum by a straight dorsosejugal suture; integument of the notogaster smooth and without ornamentation; posterior end of the notogaster slightly incurved; 10 pairs of simple, thin setae showing size differences present on the notogaster; 4 pairs of saculi with varying size and shape arranged on the notogaster; *Sa* near the insertion point of seta *te*, *S₁* located at almost level of seta *ms*, *S₂* placed slightly behind *r₃* and *S₃*; lyrifissure *im* located at the middle of notogaster, below and exterior to seta *ti*.

Ventral Region (Fig.2)

Labio-genal articulation diarthric type; infracapitulum with setae *a*, *m* and *h*, setae *h* and *m* roughened, *m* slightly smaller than *h*, seta *a* thick, stout and having fine, long barbs; apodemata II, III and sujugal apodeme well developed; apodeme II kidney shaped; epimeral area smooth, epimeral setal formula 3-2-2-3, all setae smooth, barbed and stouter except seta *1c*.

Genital plates broad anteriorly and narrow posteriorly, 3 pairs of smooth genital setae (*g₁-g₃*), *g₁* situated anteriorly, *g₂* and *g₃* placed posteriorly; seta *ag* present, inserted one on either side of the genital plate posteriolaterally; anal plates elongate having 2 pairs of smooth setae (*an₁* and *an₂*), located equidistantly from the middle, 3 pairs of adanal setae (*ad₁-ad₃*) located, *ad₁* situated posteriorly, *ad₂* laterally, slightly above insertion of seta

an_1 and ad_3 anterolaterally; lyrifissure iad in para-anal position, obliquely arranged, below seta ad_3 and slightly above the level of seta an_2 .

Legs

All legs tri- and heterodactylous, tibia III and IV with solenidia ending in a small vesicle (Figs. 3a & 3b); femora I and II stout, thick and swollen; chaetotaxy of leg I: 0-5-3(1)-6(2)-19(2).

Materials examined

3♀♀ collected from the dead spikelets of grass plant, *M. javanicus* at Kadalundi –Vallikkunnu Community reserve (11°7'37.51"N 75°49'54.64"E., Kozhikode (Dt.), Kerala, India on 16.09.2014 coll. P K. Syamjith.

Remarks

The characters present in the present specimens show very close similarity to the species *S. (S.) malabarica* erected by Ramani and Haq (1998) from the coconut palms of Kerala, South India in the possession of 3 pairs of genital setae, presence of 2 well developed rostral incisions and 4 pairs of sacculi on notogaster. It is the first report on the genus from the mangrove ecosystems of India, especially from Kerala.

Superfamily: Oripodoidea Jacot, 1925

Family: Scheloribatidae, 1933

Genus: *Scheloribates* Berlese, 1908

Subgenus: *Scheloribates (Scheloribates)* Berlese, 1908

Generic Diagnosis

Rostrum is without any apophyses; 10 pairs of notogastral setae present; 4 pairs of genital setae; 4 pairs of sacculi; legs tridactylous.

***Scheloribates (Scheloribates) praeincisus interruptus* (Berlese, 1916)**

(Plate- 35, Figs.1-2)

Colour : Dark Brown

Measurements : Length: 569-620µm

Width: 390-435 µm

Dorsal Region (Fig.1)

Prodorsum

Rostrum triangular with a blunt apex; of the 4 pairs of prodorsal setae, (*ro*, *le*, *in*, *ex*), *in* the longest; prolamellar line absent; translamellar line interrupted medially; sensillus (*ss*) with a weakly barbed, clavate head; seta *ex* weakly barbed.

Notogaster

Notogaster large, spherical in outline posteriorly; 10 pairs of notogastral setae, mostly represented by alveoli; 4 pairs of sacculi (*Sa*, *S*₁, *S*₂ and *S*₃) detected on the notogaster; fissures *ia*, *im*, and *ip* clearly visible.

Ventral Region (Fig. 2)

Infracapitulum diarthric type, infracapitular setae 3 pairs; epimeral setae roughened, show size variation, epimeral setal formula 3-2-3-2; 4 pairs of smooth genital setae present, 1 pair of aggenital (*ag*), 2 pairs of anal setae (*an*₁ and *an*₂), 3 pairs of adanal setae present; fissure *iad* para-anal in position.

Legs

All legs hetero-tridactylous in nature.

Materials examined

2♂♂ and 2♀♀ recovered from the soil/litter samples under the mangrove plant, *E. agallocha* at Pazhayangadi (12°1'36.90"N 75°16'24.05"E), Kannur (Dt) on 13.08.2012 North Kerala, India, coll. P.K. Syamjith.

Remarks

The present specimen shows very close resemblance to *S. (S.) praeincisus interruptus* described by Hammer (1972) from Fiji Island in the

possession of 10 pairs notogastral setae, nature of prodorsal setae and shape of sensillus. Hence, it is assigned to the same species.

Superfamily: Oripodoidea Jacot, 1925

Family: Oripodidae Jacot, 1925

Genus: *Protoripoda* Balogh, 1970

Generic Diagnosis.

Members possess 10 pairs of notogastral setae, 4 pairs of sacculi, 4 pairs of genital setae, 1 pair of aggenital setae, 2 pairs of anal setae and 3 pairs of adanal setae. Ano-adanal setae non-flagellate; legs tridactylous.

***Protoripoda (Protoripoda) trifoliatum* sp.nov.**

(Plate-36, Figs.1-3)

Colour : Reddish Brown

Measurements : Length: 435 μ m (435-465 μ m)

Width: 240 μ m (240-255 μ m)

Dorsal Region (Fig. 1)

Prodorsum

Rostrum widely conical, seta *ro* measures 60 μ m, barbed, incurved (Fig.1a); lamella robust, arranged marginally, connected by a linear translamella at cuspides, seta *le* 56 μ m in length, spinose apically with cilia arranged in longitudinal rows (Fig.1b); seta *in* of 52 μ m length, inserted close

to the anterior notogastral margin, phylliform, broadened towards distal apex (Fig.1c); seta *ex* not detected; *ss* with a clavate head, surface of which bears small barbs (Fig.1d); bothridial cup and base of *ss* covered by pteromorph bridge; entire prodorsal surface ornamented with small round foveoles.

Notogaster

Dorsosejugal suture more or less straight; a pair of distinctly developed lateral ridges run anteriorad along the notogaster to meet the dorsosejugal suture; 10 pairs of long and robust notogastral setae present; 4 pairs of sacculi (*Sa*, *S*₁, *S*₂, *S*₃) detected, *Sa* situated in between setae *te* and *ti*, *S*₁ just near to *ms*, *S*₂ located behind the insertion point of seta *r*₂, *S*₃ placed posteriorad, near to the insertion of seta *r*₁; lyrifissure *im* and lateral abdominal glands (*gla*) clearly visible and well developed; antero-lateral and posterior margins of notogaster marked with large foveoles, giving a wavy appearance to the notogaster border.

Ventral Region (Fig. 2)

Infracapitulum diarthric type with 3 pairs of barbed setae, *h* longer than *m* and *a*; epimeral setal formula 3-1-2-3, setae of varied shape and size, setae *1b* and *3c* barbed and long, setae *4a*, *4b*, *4c* short and smooth; entire surface of mentum and epimeres ornamented with foveoles; pedotecta I and II directed slightly forwards; discidium well developed.

Genital plates rooftop anterior portion and concave posterior; 4 pairs of small genital setae, 2 located anteriorly and 2 located posteriorly; 1 pair of small aggenital setae located mid-way between the genital plates and anal plates; anal plates with 2 pairs of short, smooth setae; 3 pairs of short and simple adanal setae inserted outside the anal opening, ad_1 located posterior of anal opening, ad_2 laterad of anal opening, ad_3 above the level with anterior border of anal opening; adanal fissure (*iad*) aligned obliquely, close to the anal plate margin; the integument of the ventral plate including that of the ano-adanal plates sculptured with punctations and foveoles.

Legs

Tarsi of all legs possess 3 claws, medial one hardly stronger than the lateral ones; leg I (Fig.3) characterized by a chaetotaxy of 1-4-3(1)-3(1)-20(2); trochanter- I bears 2 barbed setae; femur-I carries 4 setae, of which dorsal setae *d* and *l''* strongly barbed; tibia with extremely long solenidion ϕ_1 of leg I with filiform end; all leg segments ornamented with foveoles.

Etymology

The species epithet of the present new taxon is derived from the name of the mangrove associate plant species, *D. trifoliata*, with which the new species showed very close association.

Materials examined

Holotype ♀; paratype: 2♂♂ and 4♀♀ from the dead floating barks of *D. trifoliata* at Kadalundi- Vallikkunnu community reserve mangrove

(11° 7'37.51"N and 75°49'54.64"E)), Calicut (Dt.) of North Kerala on 07.10.2012, coll. P.K. Syamjith.

Type repository

The type specimen will be deposited at the Zoological Survey of India (ZSI) Calicut, Kerala, India.

Remarks

The genus *Protoripoda* was erected by Balogh (1970) with the type species, *P. (P.) woolleyi*. The genus presently includes 7 valid species viz. *P. (P.) elongata* (Oudemans, 1915); *P. (P.) incurva* (Berlese, 1916); *P. (P.) woolleyi* Balogh, 1970; *P. (P.) insularis* Balogh, 1970; *P. (P.) flagellata* Choi, 1994; *P. (P.) lineata* Mahunka, 2009 and *P. (P.) nasuta* Mahunka, 2009. The new species, *P. (P.) trifoliata* resembles the known species of the genus in the possession of 10 pairs of notogastral setae, 2 pairs of anal setae, 3 pairs of adanal setae and tridactylous legs. However, it keeps its identity separate from all the 7 known species by the long and robust nature of notogastral setae, and the presence of prominent foveoles on the dorsal and ventral surfaces of the body, including the legs. The unique character combinations observed in the present species which help to segregate it from all other known species and erect it as a new taxon are the following:

1. Prodorsum with barbed, spinose setae.
2. Prodorsal surface with variably shaped foveoles.
3. Presence of linear translamellar lines.

4. Notogaster bears a strong, longitudinal ridges/ carina and entire surface decorated with small round foveoles.
5. Long and barbed nature of epimeral setae *1b* and *3c*.

Superfamily: Oripodoidea

Family: Protoribatidae J. & P. Balogh, 1984

Genus: *Protoribates* Berlese, 1908

Subgenus: *Protoribates (Protoribates)* Berlese, 1908

Generic Diagnosis

5 pairs of genital setae, 10 pairs of notogastral setae; Epimeral setal formula 3-2-1-3; 2 pairs of anal; 2 pairs of adanal setae, ad_2 and ad_3 in para-anal position.

***Protoribates (Protoribates) capucinus* Berlese, 1908**

(Plate-37, Figs.1-3)

Colour	: Yellowish Brown
Measurements	: Length: 393-415µm
	Width : 244-255µm

Dorsal Region (Fig.1)

Prodorsum

Rostrum ends with a round tip, which appears darker than the surroundings; lamellae broad and located laterally, seta *le* barbed and as long as their distance; seta *in* shorter and barbed unilaterally; *ss* with a long, thin stalk and a lanceolate, barbed head (Fig.1a).

Notogaster

Anterior border of notogaster straight, antero lateral borders produced into large pteromorphae, which bent downward; 10 pairs of very small and thin notogastral setae present; 4 pairs of small round, equally sized area porosae (Aa , A_1 - A_3) present, A_1 located medially associated with seta ms , A_2 behind seta r_2 and A_3 near seta p_1 ; integument of notogaster ornamented with small punctations.

Ventral Region (Fig.2)

Infracapitulum diarthric type with 3 pairs of smooth, setae (a , m and h); epimeral setal formula 3-2-1-3; 5 pairs of genital, 1 pair of aggenital, 2 pairs of anal and 3 pairs of adanal setae present, all smooth; seta ad_3 located at the anterolateral corner of the anal plate, ad_2 at the posterolateral corner of anal plate and ad_1 postanal in position, ad_1 and ad_2 long while ad_3 short.

Legs

All legs monodactylous, chaetotaxy of leg I (Fig.3): 5-2(1)- 4(2)- 17(2)

Materials examined

2♂♂ and 3♀♀ recovered from the decayed leaves of *A. ilicifolius* growing in the mangrove ecosystems of Kadalundi-Vallikkunnu community reserve (11°7'54.31"N and 75°49'44.80"E) of Kozhikode (Dt).on 15.05.2012; 1♂ and 3♀♀ collected from the mangrove litters of Ezhome (12° 1'38.28"N and 75°17'0.72"E) Kannur (Dt) on 17.01.2013. coll. P.K. Syamjith.

Remarks

The present species of *Protoribates* resembles *P. (P.) capucinus* (Berlese, 1908) described from the dead leaves, near mangroves of Corolevu, Fiji Islands, in the general shape and size of the body, nature of prodorsal, notogastral, anal, genital and adanal setae. This forms the first report of the species from the mangrove ecosystems of India, especially from North Kerala.

Superfamily: Oripodoidea Jacot, 1925

Family: Haplozetidae Grandjean, 1936

Genus: *Indoribates* Jacot, 1929

Subgenus: *Indoribates (Indoribates)* Jacot, 1929

Generic Characters

Lamellae present, translamella absent; pteromorphae movable; dorsosejugal suture complete; notogastral setae 10 pairs; 4 pairs of sacculi; genital plates with 5 pairs of setae; 1 pair of aggenital, 2 pairs of anal and 3 pairs of adanal setae present.; legs monodactylous.

***Indoribates (Indoribates) punctulatus* (Sellnick, 1925)**

(Plate-38, Figs. 1-3c; Plate-39, Figs.1-3)

Colour : Dark brown

Measurements : Length: 690-765 µm

Width: 450-480 µm

Dorsal Region (Plate-38, Fig.1; Plate-39, Fig.1)

Prodorsum

Rostrum broad, seta *ro* long, curved inward and finely barbed; lamellae rather broad bearing light furrow on their entire length, seta *le* thick, stiff and barbed, longer than *ro*; seta *in* longer than *le*; seta *ex* present; sensillus flagelliform, moderately long, but slightly incrassate apically with its outer margin armed with barbs (Plate-38, Fig.1a; Plate-38, Fig.1); entire prodorsal surface covered with round foveoles.

Notogaster

Dorsosejugal suture complete; notogaster a little longer than broader and its anterolateral borders produced into short pteromorphae pitted basally; anterolateral regions strongly bent ventrad; 10 pairs of long, thin, curly setae (Plate-38, Fig.1; Plate-39, Fig.1) and 4 pairs of conspicuous sacculi present on notogaster; lyrifissure *im* located just above seta *r*₃; lateroabdominal gland (*gla*) well developed; integument micro punctate and foveolate;

Ventral Region (Plate-38, Fig.2; Plate-39, Fig.3)

Infracapitulum diarthric type; seta *a* smooth, *m* and *h* barbed (Plate-39, Fig.2); epimeral setal formula 3-1-3-2, all setae moderately long and barbed; genital plates carry 5 pairs of barbed genital setae (*g*₁-*g*₅) (Plate-39, Fig.3), seta *g*₁ projecting beyond 3*a*; each genital plate micropunctated; one pair of barbed aggenital setae present, which appear smaller than the epimeral setae; anal plates pitted, bearing 2 pairs of anal setae, both strongly barbed and longer than the aggenital setae; 3 pairs of adanal setae (Plate-38, Figs.3a-3c;

Plate-39, Fig.3) present, ad_3 barbed and pre-anal in position while ad_1 and ad_2 thick, stiff, long, strongly barbed, post-anally located in a line at the posterior border of the ventral plate; lyrifissure iad adanal in position; discidium developed as a pointed tooth; pedotectum I well developed; ventral plate ornamented with foveoles and pits of larger size than those of anal plates.

Legs

All legs monodactylous, tarsus II with 3 strong spines; femur II with very strong keel.

Materials examined

2♂♂ and 4♀♀ collected from the dead barks of the mangrove associate plant, *C.crista* present in the mangrove ecosystems of Brahmasampadam (11° 7'35.36"N 5°52'8.46"E), Malappuram (Dt.) of North Kerala on 4.12.2013, coll. P.K. Syamjith.

Remarks

The genus *Indoribates* was erected by Jacot, (1929) based on the type species *Protoribates punctulatus*. The characters of the present specimen closely resembles those of *I. (I.) punctulatus* erected by Sellnick, 1925 from Java in the nature of prodorsal setae, sensillus, the presence of foveoles on notogaster, ventral characters, presence of ventral keel on femur II etc. and hence it is assigned to the same species. This forms the first report of the species from the mangrove ecosystems of India, especially from Kerala.

Superfamily: Oripodoidea Jacot, 1925

Family: Haplozetidae Grandjean, 1936

Genus: *Trachyoribates* Berlese, 1908

Subgenus: *Trachyoribates (Rostrozetes)* Sellnick, 1925

Generic Diagnosis

5 pairs of genital setae; 10 pairs of notogastral setae (exceptionally 14);
dorsosejugal suture with 3 arches; legs monodactylous.

***Trachyoribates (Rostrozetes) ovulum ovulum* Berlese, 1908**

(Plate-40, Figs.1-2)

Colour : Brown

Measurements : Length: 320-346 μm

Width: 242-250 μm

Dorsal Region (Fig. 1)

Prodorsum

Rostrum rounded and foveolated entirely; seta *ro* small, barbed and longer than seta *le*; seta *in* shorter than *le*, inserted just above the dorsosejugal suture; *ss* swollen, ciliated and with a brush-like head; seta *ex* not detected; prodorsal surface ornamented with large foveoles.

Notogaster

Dorsosejugal suture with 3 arches; 10 pairs of smooth, slender and simple notogastral present; pteromorphae short, entire surface graced with

hard, round foveoles, imparting a wavy appearance to the lateral and posterior margins; lyrifissures *ia* and *im* visible distinctly.

Ventral Region (Fig.2)

Camerostome almost oval in shape; infracapitular setae 3 pairs, epimeral surface foveolated, epimeral setal formula 3-1-2-2, all setae, minute, simple and smooth; anogenital plates placed distantly; genital plates small with 5 pairs of simple, minute setae; aggenital setae 1 pair, simple, minute and short; anal plates rectangular in shape; 2 pairs of simple anal and 3 pairs of adanal setae detected; fissure *iad* placed in between setae *ad*₂ and *ad*₃; the whole ventral surface foveolated in nature.

Legs

All legs monodactylous.

Materials examined

2♂♂ and 3♀♀ recovered from the soil samples of the mangrove ecosystems of Ezhome (12°02'57.54"N 75°27'71.60"E) Kannur (Dt.) on 16.01.2013, North Kerala, India, coll. P.K. Syamjith.

Remarks

The genus *Trachyoribates* was erected by Berlese, (1908) based on the type species, *T.ovulum*. The present specimen collected from the mangrove ecosystems of Kadalundi shows very close resemblance to *T. (R.) ovulum ovulum* erected by Berlese (1908) in several features like the nature of

dorsosejugal suture, presence of foveoles on the dorsal and ventral surfaces, nature of prodorsal setae, shape of sensillus and similarities in the epimeral setal formula.

Family: Haplozetidae Grandjean, 1936

Genus: *Trachyoribates* Berlese, 1908

Subgenus: *Trachyoribates (Rostrozetes)* Sellnick, 1925

***Trachyoribates (Rostrozetes) nortoni* sp.nov.**

(Plate -41, Figs. 1-3)

Colour : Brown

Measurements : Length: 320-346 μm

Width: 242-250 μm

Dorsal Region (Fig.1)

Prodorsum

Rostrum rounded and incised; seta *ro* short, smooth and measures 15 μm (Fig.1b); seta *le* longer than seta *ro*, measuring 25 μm and with serrated outer margin (Fig. 1c); seta *in* shorter than *le*, measuring 14 μm (Fig.1d), inserted just above the dorsosejugal suture; *ss* swollen, incrassate and aciculate at its head (Fig.1a); seta *ex* not detected; prodorsum carries large foveoles.

Notogaster

Dorsosejugal suture with 3 arches; 10 pairs of notogastral setae present, all smooth, slender and simple; pteromorphae short, stumpy and curved ventrad; each pteromorph with characteristic anterior notch

ornamented with dense round foveoles; notogaster bears longitudinal undulating ridges, each ridge reaches the base of the pteromorph; entire notogastral surface ornamented with round foveoles irregularly, imparting a wavy appearance to the posterolateral margins.

Ventral Region (Fig.2)

Infracapitulum not alveolated; mentotectum carries closely set hard striae; infracapitular setae 3 pairs, all smooth; epimeral surface foveolated, epimeral setal formula 3-1-2-2, all setae simple and smooth; anogenital plates well separated; genital plates small, about half of the size of the anal plates, bearing 5 pairs of simple, minute setae; aggenital setae 1 pair, simple and short; anal plates rectangular, carrying 2 pairs of minute, simple, smooth setae (an_1 and an_2), arranged along the lateral margin of the anal plates; 3 pairs of simple adanal setae detected, ad_1 post-anal in position, ad_2 para-anal and ad_3 at the anterolateral corner of the anal plate; fissure iad obliquely placed, in between setae ad_2 and ad_3 ; the whole ventral surface including anogenital plates and epimeres ornamented with round foveoles.

Legs

All legs monodactylous, chaetotaxy of leg I (Fig.3): 5-2(1)-2(1)-20(2), surface of femur I ornamented with large round foveoles.

Etymology

The new species is gratefully dedicated to Dr. Roy A. Norton, Professor (Rtd.), State University of New York, USA, who helped very much

for the conduct of taxonomic studies by supplying all relevant literature for the identification of various species.

Materials examined

Holotype ♀; paratypes: 4♂♂ and 5♀♀ recovered from the soil/ litter samples at Nileswaram (12°15'58.03"N 75° 7'13.61"E) Kasaragod (Dt.) of North Kerala on 26.05.2011, coll. P.K. Syamjith.

Type repository

The type specimen will be deposited at the Zoological Survey of India (ZSI) Calicut, Kerala, India.

Remarks

The genus *Trachyoribates* was erected by Berlese, 1908 based on the type species, *Oribata ampulla*. At present, this genus comprises 29 valid species. The present new species, based on the possession of 10 pairs of notogastral setae and striations on mentotectum can be easily differentiated from other known species such as *T.(R.)dimorphites* Higgins, 1966 (13pairs of setae); *T.(R.)geminisetosus* Balogh and Mahunka, 1976 & *T.(R.)heterotrichous* Pérez-Íñigo and Baggio, 1991 (11 pairs of setae each) ; *T.(R.)pseudofurcatus* Balogh and Mahunka, 1968 (12 pairs of setae) and *T.(R.)pinguis* Balogh and Mahunka, 1978 (14 pairs of setae) . The possession of 3 pronounced arches on the dorsosjugal suture of the present species easily separates it from single arched species like *T.(R.)bothulifer* Balogh and Mahunka, 1979; *T.(R.)polygonatus* Balogh and Mahunka, 1969; *T.(R.)*

geminisetosus Balogh and Mahunka, 1978; *T.(R.)perzinigoi* Balogh, 1995; and *T.(R.)pinguis* Balogh and Mahunka, 1978. Possession of 5 pairs of genital setae and striated mentum separates the new species from *T.(R.)heterotrichous* Pérez-Íñigo and Baggio, 1991 & *T.(R.)pseudofurcatus* Balogh and Mahunka, 1968 (4 pairs of genital setae in both species). Presence of 3 pairs of adanal setae of the present species segregates the new species from the known species with 2 pairs of adanal setae viz. *T.(R.)aegypticus* Yousef and Nasry, 1976; *T.(R.)africanus* Yousef and Nasry, 1976; *T.(R.)dimorphites* Higgins, 1966; *T.(R.)monstruosus* Balogh and Mahunka, 1969; and *T.(R.)perzinigoi* Balogh, 1995. Possession of irregularly margined flower like foveoles in *T.(R.)florens* Balogh, 1970) separates it from the new species which possesses integument with normal foveoles. The following character combinations present in the new species keep its identity separate from all the known species of the genus.

1. Elongated and spinose nature of sensillus
2. Absence of seta *ex*.
3. Presence of closely set thick striae at the base of the mentotectum.

Superfamily: Galumnoidea Jacot, 1925

Family: Galumnidae Jacot, 1925

Genus: *Galumna* Heyden, 1826

Subgenus: *Galumna* (*Galumna*) (Heyden, 1826)

Generic Diagnosis

Lamellar and sub lamellar lines well developed; lamellar setae inserted between lamellar lines (L) and sublamellar lines (S); notogatal setae

represented by 10 pairs of microsetae or alveoli; notogaster rounded posteriorly, with true porose areas; 6 pairs of genital setae; all legs tridactylous.

***Galumna (Galumna) paragibbula* Weigmann, 2011**

(Plate 42, Figs.1-2)

Colour : Yellowish brown

Measurements : Length: 360-395µm

Width: 240-275 µm

Dorsal Region (Fig.1)

Prodorsum

Rostrum rounded in appearance; seta *ro* short, ciliated; seta *le* smooth, very short, near lamellar line, arises between lines *L* and *S*; seta *in* short, seta *ex* minute; *ss* moderately long, with slender fusiform, ciliated, head (Fig.1a).

Notogaster

Dorsosejugal suture medially broken; in middle between 2 porose areas *Ad* present near dorsophragma; notogastral setae represented by 10 pairs of alveoli in typical positions; 4 pairs of porose areas, *Aa* the largest, *A*₁- *A*₃ rounded; pteromorphae well developed, movable and typical for the genus; lyrifissure *ia* located on pteromorph, *im* located just above the porose area, *A*₁; opisthonotal gland opening (*gla*) located antero-laterally to *A*₂; median centro-dorsal pore present.

Ventral Region (Fig.2)

Infracapitulum bears 3 pairs of minute, simple setae *a*, *m* and *h*; Epimeral setal formula 1-0-2-1, all setae minute and simple; 6 pairs (*g*₁-*g*₆) of setiform, thin, smooth genital setae present, the first 3 pairs (*g*₁-*g*₃) located on anterior border of genital plates; one pair of aggenital (*ag*), 2 pairs of anal (*an*₁-*an*₂) and 3pairs of minute adanal setae (*ad*₁-*ad*₃) present; adanal lyrifissure (*iad*) located lateral to the anal plate and seta *ad*₃.

Legs

All legs tridactylous in nature.

Materials examined

3♂♂ and 1♀ collected from the soil samples of the mangrove ecosystems at Kadalundi –Vallikkunnu community reserve, (11°7'37.51"N 75°49'54.64"E) Calicut (Dts.) of North Kerala on 17.11.2011 coll. P.K. Syamjith.

Remarks

The present specimen of *Galumna* collected from the mangrove soils of Kadalundi shows very close affinity with *G. (G.). paragibbula* erected by Weigmann (2011) from the rocky areas of the coastal habitats of South-West Portugal in the nature of prodorsal and notogastral setae, medially indistinct nature of dorsosejugal suture and arrangement of area porosae . The present recovery of the species forms the first report of the species from India, especially from Kerala.

CHAPTER 8

INTRODUCTION

Oribatid mites are commonly called as the “moss mites or beetle mites”. They are known to serve as one of the most numerically dominant groups of arthropods in every organic soil horizon, inhabiting in a wide variety of microhabitats like the litter, humus layers, lichens, moss, algae, fungal cushions and in the bark of trees, mangrove pneumatophores and tidal debris. From an economic point of view, oribatid mites have drawn special attraction of the world renowned acarologists in terms of their direct or indirect effects on mankind and areas of human interest. These mites are known to act as efficient agents in biodegradation and nutrient cycling, bioindication, biological control etc. and are known to help in detection of post mortem interval and thus in forensic science even.

In soil, the microbial populations have limited abilities to move from one place to another. Once the energy of a particular substrate becomes limited or consumed entirely, the existing microbial biomass shuts down and remains inactive until the availability of new sources. This has been referred to as the ‘Sleeping beauty Paradox’ (Lavelle *et al.* 1994; Lavelle 1997). The senescent microbial colonies get rejuvenated only through the ‘kiss’ of grazing arthropods including the dominant members like soil mites. This rather deep kiss (ingestion) by the soil mites results in the mixing up of

microbial propagules with fresh resources in the fecal pellets, and helps to transport these microbes from one place to another.

Despite their extreme diversity and species complexity as met with in forest ecosystems and litter-accumulated areas, oribatid mites exhibit low distribution trend and species composition in mangrove ecosystems and coastal areas. A better understanding of the feeding habits is essential for assessing their influence on soil fertility, especially in mangrove soils. In spite of the richness and the diversity of the soils in India, the studies so far done on the oribatid diversity, function and ecological aspects are extremely limited. This is especially true in the case of mangrove ecosystems, which still represent an unexplored realm as far as the oribatid diversity is concerned.

Schuster (1956) divided the oribatid mites into 3 major groups based on their diverse feeding habits viz. 1) Macrophytophages- feeding on higher plant substrates; 2) Microphytophages- feeding on microflora and 3) Non-specialists. Later, Luxton (1972) reviewed and modified this classification by introducing terms like Panphytophages as a substitute for Non-specialists and by adding more terms like 4) Zoophages- feeding on living animal materials, 5) Necrophages –feeding on carrion and 6) Coprophages – feeding on faecal materials. The nutritional flexibility of stenotopic (organisms able to tolerate only a restricted range of habitats or ecological conditions) oribatid mites inhabiting mangrove / marine littoral zones are not to be studied in detail but

some truly intertidal mites like *A.inexpectatus*, *F. atlantica* and *C. bermudensis* are reported to be clearly as algivorous. Most of the marine littoral oribatids are considered as opportunistic feeders and some species are supposed to be categorized as carnivorous.

Concerning the reproductive biology of mangrove/marine littoral oribatid mites, an elaborated study does not exist. The reproductive mode of major intertidal oribatid mite species remains unknown. This can be attributed to some experimental difficulties met with in the culturing of intertidal mites under laboratory conditions.

The present study, apart from exploring the taxonomic diversity of mangrove dwelling oribatid mites was also extended to gather information on the nutritional and developmental biology of two representative species viz. *H. epimeratus* gen.nov.sp.nov and *A. clavata* (Markel, 1964) under laboratory conditions. Studies on the feeding and breeding biology of these species were carried out under laboratory conditions at a temperature of $28 \pm 2^{\circ}\text{C}$ and RH of $79 \pm 2\%$ and saline water $\text{pH} \approx 7.9 \pm 2$, collected from the natural habitat. Detailed studies on their microhabitat preference, morphological modifications with respect to changes in the mangrove environments, morphological features of all juvenile stages etc. were studied; data were recorded and presented through figures and tables.

CHAPTER 9

REVIEW OF LITERATURE

The dynamic mangrove ecosystem supports numerous soil microbes and a rich diversity of microarthropods. Such a diverse assemblage of arthropod fauna play very significant role in the degradation / decomposition of the organic available in the mangrove soils. A perusal of the available literature on the biological, behavioural and life history strategies of oribatid mites revealed an extremely limited level of research work on these mites and infact the mangrove dwelling oribatids and related groups of intertidal mites still remain as an unexplored entity. Accordingly, there is a dearth of knowledge on the feeding and breeding biology of the mangrove and intertidal group of mites. The multiple types of interactions exhibited by these mites with their extremely challenging ecosystem offer a better ground for the initiation of future intensive explorations to unravel the precise impact of these faunal ingredients in their microhabitats. In this respect, the review of literature presented here is an earnest attempt to amalgamate the available scanty and scattered information on the feeding and breeding aspects of intertidal (mangrove) /seashore /coastal/ littoral dwelling oribatid mites. Additionally, the present review also incorporates the data available on the

feeding habits of oribatid mites from algae, lichens and decomposing leaf litter etc.

Jacot (1934) enlightened our knowledge on the intertidal moss mites in America and he recorded a truly intertidal species of the genus *Ameronothrus* viz. *A.spoofi* from the sub-saline unicellular algae coated over the rocks . He reported that the distribution of the species was limited by two factors viz. viviparity as well as the availability of rocks with crannies and fissures.

Hayes (1963) conducted studies on the feeding preference of some Phthiracarid mites on six stages (I-VI) of the decomposing leaf litter of the each of the three conifers viz. *Abies grandis*, *Picea sitchensis* and *Pinus sylvestris* under laboratory conditions. The mites *Hoploderma magnum*, *Phthiracarus piger* showed significant preference to feed on stage V litter whereas *Oribotritia loricata* preferred the most decayed materials.

While studying the ecology of salt marsh acarina, Luxton (1964) discussed and analysed the factors, which could affect the seasonal variations among acari, including the oribatid mites of the seashore. The same author (1967) reported that mechanical action of the tidal wave exerted an important role in regulating the occurrence of egg laying mites in marine littoral habitats. Polderman (1974a) conducted studies on oribatid mites of 4 salt marshes in Denmark and he could identify distinct zonation pattern among the salt marshes as well as their oribatid faunal elements. Zonation pattern was

more pronounced in the halophilous species of Skallingen marshes where the average salinity of seawater is considerably lower. The same author (1974b) made an investigation on the oribatid mites inhabiting saline areas in the Netherlands with particular reference to their association with vegetations of saltmarshes. He recorded the association of species like *Hermannia subglabra* and *Punctoribates quadrivertex* with the algal materials of saline areas.

Weigmann (1975) made a comparative observation on the life cycle of the salt marsh dwelling oribatid mite, *H. subglabra* as well as the salt marsh free species, *Platynothrus peltifer* in both laboratory and field conditions. *H. subglabra* completed its life cycle with the minimum time and its development from egg to adult was completed within 117 days at 15°C.

Schulte *et al.* (1975) made an elaborate study on the distribution and ecology of Ameronothrid mites with respect to their varying habitats. The authors classified the marine littoral mites as stenotopic inhabitants, confining exclusively to the coastal environment. The adults and nymphal stages these mites were found to possess certain adaptive features to thrive on filamentous green algae in conditions during and in between floodings.

Burford (1976) conducted a study on the morphology and life history of a new species of aquatic oribatid mite, *Hydrozetes bushnelli* from pond habitats of Colorado. He reported parthenogenesis and oviparous mode of life cycle along with data on their amphibious plastron respiration. These mites

showed some opportunistic feeding pattern on filamentous algae, wood fibers, detritus and decaying plant and animal materials. Weigmann and Schulte (1977) analysed the evolutionary pattern of Ameronothrid mites based on the morphological characters of the adults and nymphal stages.

Schuster (1979) noted that many species of the salt marsh oribatids, especially those living on intertidal rocks could feed on green algae. Goddard (1979) studied the feeding biology of 9 species of free-living Acari at Signy Island, South Orkney Islands and observed that *A. antarcticus* and *H. belgicae* could feed exclusively on organic detritus, lichens and algae.

Krantz and Baker (1982) made a discussion on the plastron respiratory mechanisms in an aquatic oribatid mite, *Hydrozetes* sp. and compared these with the peritrematic respiration mechanisms of two gamasid mites and showed some differences in the cuticular plastron bed structures.

Luxton (1982) conducted studies on cryptostigmatid mites inhabiting the beech woodland soil, East Jutland with respect to their breeding and nutritional biology and he observed that the greatest numbers of eggs were carried by litter dwellers and they possessed species-specific overwintering period with seasonal reproductive rhythms. Harding and Easton (1984) conducted detailed studies on the development of 2 species of Phthiracarid mites viz. *Steganacarus magnus* and *Phthiracarus anonymum* in beech cupules. The authors observed that *S.magnus* required 2-4 weeks period for

the prelarval development while for 1-6 months for *P. anonymum* and 1-year period for the development in larvae and tritonymphs of *S. magnus* in autumn buried cupules.

Sømme and Block (1984) conducted experiments on the ecophysiology of two species of intertidal mites viz. *Halozetes marinus* and *Hyadesia maxima* under laboratory and field conditions. They found significant results on the physiological adaptations to the life in the littoral zone under extreme climatic conditions. These mite showed heat tolerance during the summer and cold hardiness during winter seasons and no stress was found in anoxic conditions.

Seyd and Seaward (1984) classified oribatid mites into different groups based on the ecological requirements such as association with lichens. The authors also provided information on the feeding activity of these mites based on the culture – feeding observations. Pugh *et al.* (1987) studied the ambulacral modification among the intertidal Acari in relation to their life style. The mesostigmatids possessed elongate, strong pulvillar sclerites while the members of the genus *Ameronothrus* possessed proportionately longer claws.

Norton *et al.* (1988) gave an account on the biological aspects of an aquatic oribatid mite *Mucronothrus nasalis* inhabiting in a coldwater habitat of Canada. He traced the generalized grazing behaviour of both the adults and

immatures on unicellular filamentous green algae, fungi and on other substrate surfaces.

Dastych (1990) added notes on the adults and ontogenic stages of some Antarctic mites. Luxton (1990) summarized data on the distribution pattern, feeding biology, activity rhythms and adaptations in marine littoral mites of the Newzealand region. He classified mite fauna into 2 groups namely strictly marine and strictly terrestrial based on special morphological and physiological adaptations to marine environment. Pugh *et al.* (1990) conducted detailed studies on the plastron respiration in a Fortuyniid mite, *Fortuynia maculata* with respect to the specialized paired tracheal structure called the van der Hammen's organ, seen in association with the acetabular cavities and bothridia.

Convey (1994a) conducted experiments on the growth and mortality rates of adults and 3 juvenile instars of *A. antarcticus* for a period of one year and found rapid growth during the short summer period. The same author (1994b) made comparative observation on the sex ratio, oviposition strategies and early development under both natural and laboratory conditions (temperature 7°C). The differences in egg contents suggested differences in two species viz. *A. antarcticus* and *H. belgicae*.

Block and Convey (1995) conducted studies on the ecophysiology, life history and biology of the maritime Antarctic mite, *Alaskozetes*

antarticus. They also provided information on the physiological specializations such as overwintering survival by super cooling, low enzyme activation energies and optimum temperatures for feeding and growth of the species.

The compact multi-instar aggregation and life strategy in the Antarctic oribatid mite, *Maudheimia wilsoni* were analysed by Marshall and Convey (1999) and they suggested that such behaviors were essential for the mites, especially for the juvenile instars, for making them capable of overwintering and for adults, which faced a limited annual growing period.

Bucking (2002) studied the three-dimensional structures of the gut systems of *A. lineatus* by making serial sections and he observed an additional subunit of the gut, between the colon and postcolon. Søvik (2003) provided information on the occurrence of ovoviviparity and mixed parity modes of reproduction in Arctic populations of *A. lineatus*. The same author (2004) provided data on the biology and life history of Arctic populations of *A. lineatus* and further reported a 5-year life cycle (larva to larva) and adult survival period for 2-3 years in the Arctic larviparous populations.

Karasawa and Hijii (2004) analysed the modifications in the morphology, structure, number, shape and size of the claws in mangrove dwelling oribatid mites. They reported that oribatid species dwelling on

flooded trunks and littoral algae tridactylous condition was approximately zero whereas it was 20% among forest floor dwelling oribatid mites.

Marshall and Convey (2004a) reported latitudinal variations in habitat specificity among the Ameronothroid oribatid mites. Marshall and Proches (2007) hypothesized on the origin of marine forms of oribatid (Ameronothroidea) and Astigmatid (Hyadesioid) mites based on their geographical, ecological and taxonomical patterns. Seniczak *et al.* (2007) studied and proposed systematic position of two aquatic oribatids viz. *Hydrozetes lacustris* and *H. octosetosus* based on their ecology and juvenile morphology.

Belozerov (2008) reviewed the significant role of diapause and quiescence as adaptations to predictable (seasonal) and unpredictable (irregular) environmental changes in mites and ticks. Crisper and Schuster (2008) gave information on the feeding and life history of “thalassobiontic” oribatid mites inhabiting the rocky shores of Bermuda Islands and they reported that the larvae of *F. atlantica* hatched after 15-16 days.

A molecular based study to reveal mite dispersal among the Southern Ocean Islands and Antarctica carried out by Mortimer *et al.* (2010) revealed significant habitat preferences and dispersal (marine intertidal versus terrestrial /supralittoral) among Ameronothroid mites. Hawes *et al.* (2010) detected phenotypic plasticity of cold acclimation in the Antarctic mite,

H.belgicae which possessed both “plastic and superplastic” (extreme plasticity) acclimation responses under laboratory and field condition. Ermilov (2011) described the morphological features of the juvenile stages of *A.ardua*. Ermilov *et al.* (2012) gave information on the morphology of the juvenile instars of several species of the family Ameronothridae viz. *A. antarcticus intermedius*, *A.lineatus*, *H. crozetensis* and *Pseudantarctica georgiae*.

Pfingstl and Schuster (2012) recorded the association of true intertidal oribatid mites viz. *C.bermudensis*, *C. trifoveatus* and *C. mangrovi* dwelling in different intertidal algae growing sandy, rocky and muddy substrates as well as on the roots of mangrove plants like *Rhizophora mangle* and *A.germinans*. Pfingstl (2013) provided information on the biology and life history of members of intertidal mite family Selenoribatidae. He reported the details of the life stages including the morphological features of Apherodermous juvenile instars. The same author (2013b) studied the hydrochorous dispersal of intertidal oribatid mites and their resistance to fresh water and saline water and reported that the maximum submersion time ranged from 40 to 143 days. Subsequently, the same author (2013c) presented a compiled report on the ecology of Fortuyniid and Selenoribatid mites of the Bermuda Islands. He examined the habitat use, locomotion, food preference, moulting and reproduction strategies under laboratory conditions and suggested that

behaviors like opportunistic feeding, fast moving and climbing excellence and floating were adaptations to challenging environments.

Syamjith and Ramani (2013) conducted studies on the association of a mangrove dwelling Euphthiracarid mite, *A. clavata* with the algal species viz. *Microspora* sp. growing on the pneumatophores and barks of the true mangrove plant, *A. marina*. The authors reported the boring and tunneling activity of the adults and nymphs of the species on the pneumatophores and bark and the presence of the developmental stages inside the tunnels.

Gan *et al.* (2014) conducted studies on the feeding habits of oribatid mites in the changing environment and they concluded that organisms with generalist diets were more flexible in their feeding habits than the specialist feeders and they were affected less by the environmental changes.

CHAPTER 10

MATERIALS AND METHODS

I. SAMPLE COLLECTION AND EXTRACTION OF SELECTED SPECIES FOR BIOLOGICAL STUDIES:

In the present study, two species of mangrove dwelling oribatid mites viz. *A. clavata* and *H. epimeratus* were considered for making detailed observation on feeding habits and developmental biology. Both the species showed their occurrence in mangrove ecosystems during most of the sampling occasions. Samples of soil, litter, dead pneumatophores, barks, decaying twigs etc. were collected from the floor of selected mangrove forests viz. Brahmasampadam, Kadalundi- Vallikkunnu community reserve mangrove and Kottakkadavu of North Kerala. Live specimens of *A. clavata* were extracted from the dead, decaying pneumatophores and barks of the true mangrove plant, *A. marina* through direct examination under a stereozoom microscope or through extraction under the open brass funnel apparatus. The live mites directly hand sorted under the stereozoom microscope were transferred species-wise with the help of a camel hair brush in to plastic culture vials of 4x6cm based with a mixture of Plaster -of- Paris and charcoal in (4:1 ratio). The culture bases were adequately moistened with saline water collected from the same habitat and maintained under controlled laboratory

conditions and the mites were reared on test food items comprising moistened leaf pieces/ decayed piece of moistened barks, pneumatophores etc. of *A. marina* collected from their natural habitats.

Live specimens extracted through the open bass funnel apparatus in to water were examined under a stereozoom microscope. Specimens of the above two species were segregated with the help of a moistened camel hair brush and transferred species wise in to collection vials and reared as mentioned above. These culture cells were kept as stock cultures of the species and the mites were allowed to be acclimatized with the experimental conditions in the culture cells. Saline water was added to the culture cells as and when required.

II. BIOLOGICAL STUDIES ON SELECTED SPECIES OF MANGROVE DWELLING MITES

The most active and healthy individuals of the above two species were segregated from the stock cultures and reared separately for making further observations on the feeding and breeding aspects.

1. Studies on Feeding Biology

Observations on the feeding habits of two species of mangrove inhabiting mites viz. *A. clavata* and *H. epimeratus* were carried by adopting both qualitative methods.

2. Qualitative Assessment of Feeding Habits:

Mangrove samples, including the decomposing litter, twigs, barks and pneumatophores of *A. marina* were collected from the study sites were subjected to direct examination under a stereozoom microscope in the laboratory for recording data on the general nature of feeding of the two selected species viz. *A. clavata* and *H. epimeratus* on the natural food items. Data on the nature of feeding, production of fecal pellets and the type of food selected by adults and nymphal stages were collected through microscopic observation and recorded. The nature of feeding and the feeding preference to the various food items were studied through food choice test.

III. FOOD CHOICE TEST

Food choice test was performed under laboratory conditions with the various natural food items, offered as test food items and recording the feeding preference of *A. clavata* to individual food item. For this, cafeteria experiment, as mentioned below was conducted to assess the feeding preference.

1. Cafeteria Experiment on *A. clavata* (Plate- 43, Figs.1-3)

Live specimens (25 Nos.) of *A.clavata* (Fig.1) were segregated from the stock cultures and were brought up in to a culture cell (volume 40 ml, 35mm diameter and 55mm height). These mites were offered with small

quantities of various test food items collected from their natural habitat, arranged in a circle in the culture vial (Cafeteria: **HUBERT 2003**, with slight modification) (Plate- 43, Fig.2). This set up was made to ensure equal accessibility to the mites for all the test food items offered. Five such replicates (culture vials) were maintained under controlled laboratory conditions for making repeated observations. Mites in each cafeteria set up were subjected to microscopic observation at different time intervals (24, 48, 72, 96, and 120 hours) to record their response to individual food item, mode of feeding etc. The presence of individual mites on each food item as well as the reduction in food size, nature of feeding etc. were considered as the indication for assessing food consumption by the mites. The feeding Preference of the selected species of mites to each of the test food item was evaluated based on the following criteria:

- ▶ Presence of the mites near/adjacent/ or among the food items supplied.
- ▶ General response and feeding activity of mites in cultures.
- ▶ Presence of feeding marks or signs produced on the food surface in the form of the feeding holes/ burrows on the leaves, skeletonization of the leaves, tunnels on wood particles etc.
- ▶ Presence and number of fecal pellets laid on/around food materials or on the substratum.
- ▶ Positive signs of feeding by the immature life stages, leading to completion of their life cycle.

1. Quantitative Assessment of Feeding rate of *A. clavata* on the Preferred Food item (Pneumatophores)

Quantitative assessment of the rate of feeding of the juvenile and adult stages of *A. clavata* was made under laboratory conditions on the moist preferred food item, as revealed through the cafeteria experiment, viz. the pneumatophores of the true mangrove plant, *A. marina*. For this, 15 adults and 10 nymphal stages of *A. clavata* were transferred to individual culture cells and reared only on the preferred food item comprising the pieces of sectioned pneumatophores (to facilitate easy and clear observation of feeding activity) (Plate-43, Fig.3). The culture base was frequently moistened with saline water of pH $\approx$ 7.9, collected from the natural mangrove ecosystem. Observation was made at different time intervals (24, 48, 72, 96, 120 and 144 hours) to record the feeding activity. The faecal pellets produced at the different time intervals were separated and counted. The number of faecal pellets produced at different time intervals was taken as the index to measure the rate of feeding of the species.

III. DEVELOPMENTAL STUDIES OF SELECTED ORIBATID

MITES

Studies on the postembryonic development of the above two species were carried out under laboratory conditions by rearing them in plaster culture cells as described above, on their most preferred food items like dead

mangrove pneumatophores, barks and litter residues. The culture cells containing the live individuals were regularly observed under a stereozoom microscope with the minimum light intensity. For easy observation, individual mite species with its ontogenic stages (larva, 3 nymphal stages) was reared separately in the cultured cells (Plate- 43, Figs.4-6). Frequent observations were made to collect information on various developmental aspects like incubation, hatching, active stages, quiescent periods, moulting etc.

The developmental studies were carried out at controlled room temperature of $28\pm 2^{\circ}\text{C}$ and Relative Humidity $\text{RH} = 79\pm 2\%$.

E. Quantitative Analysis of Micronutrients Present in Soils with and without Oribatid mite Samples.

Soil samples collected from oribatid mite rich mangrove ecosystems were analysed with respect to their levels in micronutrients like Nitrogen, Phosphorous and Potassium. For quantitative analysis, soil samples were collected from a specific site which supported the maximum population of oribatid mites as evidenced through the results of sampling was selected as the experimental plot. As control samples, soils from a site which possessed relatively very few density of oribatid mites were collected. Both the control and experimental samples were subjected to extraction for removing the entire oribatid mites and subjected to analysis of nutrients like N, P and K. carried

out from the Soil testing Laboratory of the CWRDM, Calicut. Statistical analysis of the results obtained on nutrient analysis was performed separately for the control and experimental samples, using the statistical package SPSS 17.0.

CHAPTER 11

OBSERVATION

I. QUALITATIVE AND QUANTITATIVE ANALYSIS OF FEEDING HABITS:

Feeding Habits of *A.clavata* on Dead Components of the Mangrove Plant, *A.marina* (Plate-44, Figs. 1-8)

Results of field sampling revealed the presence of a number of oribatid mites in association with the true mangrove plants as well as the mangrove associates from the various sites screened. The various life stages of the euphthiracarid member, *A. clavata* were found aggregated on the dead bark of *A. marina* (Plate-44, figs. 1&2), showing a very close association with the filamentous green alga, *Microspora* sp. All the life stages viz. egg, larva, three nymphal stages (proto-, deuto- and tritonymph) and their respective quiescent phases could be recovered from the algal filaments. The members of the species were found to feed simultaneously on the filaments of *Microspora* sp. as well as dead bark of *A. marina*. Progressive feeding activity of various life stages of *A. clavata* was found to produce feeding tunnels on the bark of *A. marina*. (Plate-44, Figs. 3&4). The alimentary tracts of the transparent larvae and nymphs of the species were found to harbour varying numbers of green coloured food globules, on consumption of *Microspora* sp.

(Plate -44, fig. 5). Both the fresh and decayed filaments of *Microspora* sp. were found initially nibbled by the various life stages of the mite and later on exhibited voracious feeding trend (Plate- 44, fig.6). As a result of voracious feeding activity, masses of faecal pellets were found accumulated in the culture base/feeding substrate (Plate- 44, fig.7). Intensive feeding by the adults and nymphs produced large amounts of brown and green coloured faecal pellets in the culture cells. (Plate- 44, Fig. 8)

b. Food choice test: (Plate- 45, Figs.1-8)

The results of the cafeteria experiments conducted under laboratory conditions revealed the preference of *A. clavata* to the dead pneumatophores, on which the species fed very actively (Plate -45, fig. 1). The nymphal stages of *A. clavata* showed preference to leaves of *A. marina* and they actively fed on these and laid dark coloured faecal pellets, which were accumulated in the culture cells. The maximum number of mites could be located on dead pneumatophores of *A.marina*, followed by the dead bark covered with filaments of *Microspora* sp. and dead leaves of *A. marina*. Only lesser number of mites could be detected on the dead leaves of *A. ilicifolius* on which the presence of feeding signs was less evident. The number of mites showed an increase with the advancement of decay of the pneumatophores (Plate -45, figs. 2-4)

On the most favoured food item (dead pneumatophore of *A. marina*) the feeding activity by the larval and nymphal stages was found to commence at a low level in the initial stage and it progressively enhance to reach the maximum level from the 12th hour onwards. This feeding trend was continued along the region of cortex (gas- filled aerenchyma cells) (Plate-45, Figs.5-6a&b), the pith and xylem vessels of pneumatophore (Plate -45, Fig.6c), till the exhaustion of the feeding substrate except the the epidermal tissue and pericycle regions, which were found totally excluded and left behind in the culture cell (Plate- 45, Fig.8). The larvae and nymphs of this species were found to contain 1-3 brown coloured food boli inside their alimentary tract (Plate-45, Fig.6d). Accumulation of masses of faecal pellets was a common feature in culture cells, where the species was reared on dead pneumatophores of *A. marina*. The adults and nymphal stages exhibited more preference to the gas-filled aerenchymatous tissue of the dead pneumatophores, especially in advanced stages of decomposition and more number of mites were found congregated on such regions (Plate- 45, Fig.7)The unfed remnants of the pneumatophores accumulated in the culture cells often offered adequate ground for fungal growth (Plate- 45, Fig.8) subsequently.

C. Feeding by Different Oribatid species on Diverse Mangrove Litter Substrates (Plate- 46, Figs. 1-8)

In the present study, the adults of *I. (I.) punctulatus* and *P.(P.) trifoliatus* were found very actively feeding up on the decomposing woody parts of the mangrove associate plants like *C. crista* and *D.trifoliata*. Both the species produced feeding tunnels inside the decomposed bark, and these tunnels were found packed with large amount of dark brown coloured faecal pellets (Plate- 46, Figs.1-5). Most of the field collected oribatid species consumed the soft tissues of decayed pneumatophores, mangrove leaves and other littoral components. The feeding activity of members representing species like *P. (P.) capucinus*, *Nothrus* sp., *J. (J.) porosus*, and nymphs of *I. (I.) punctulatus* etc. on different litter components comprising dead mangrove leaves of *A. ilicifolius*, *A.marina* and *A. officinalis* (Plate -46, Figs. 6a-d), resulted in the skeletonization of leaf tissues, (Plate-46, Figs.7-8) formation of boring holes and tunnels on the wood, bark pneumatophores etc., ultimately leading to the conversion of these materials in to faecal pellets . Actively feeding nymphal stages of the above species also could be recovered from the small crevices and holes present on the decomposing barks and twigs of mangrove plants collected from the field.

D. Microhabitat preference/association and morphological modifications (Plate-47, Figs.1-5e)

Studies on the microhabitat preference of selected species revealed their specificity to rely on different vegetations including the spikelets of a mangrove associate grass plant, *M. javanicus*. The latter was found to grow up to 2 meters in height from the ground level and which was selected as the most preferred food item by the species, *S. (S.) malabarica* (Plate- 47, Figs.1-1c). The dead and decomposing spikelets of the grass offered the preferred microhabitat for the replenishment of the species. The dead pneumatophores of the mangrove plant, *A. marina* were found to serve as very challenging shelter to *A. clavata*. (Plate-47, Figs. 2-2c). A close association of *I. (I.) punctulatus* on dead, decomposing barks of *C. crista* was also noticed (Plate-47, Figs.3-3b). The new oribatid species viz. *P. (P.) trifoliata* sp.nov. (Plate-47, figs.4-4b) and *P. kadalundiensis* sp.nov., were found in associated with mangrove plant *D. trifoliata* and the dead leaves of twigs of *A. marina* respectively. Moreover, results of field cum laboratory observations revealed the possession of monodactylous condition in species dwelling in soil/ litter and tridactylous condition for species inhabiting arboreal (canopy dwelling) forms of oribatid mites. The littoral dwelling oribatid species like *S. mangrovius* sp.nov., possessed monodactylous condition with longer, hooked, sickle shaped claws bearing prominent proximoventral tooth. Arboreal forms

generally were characterized by tridactylous legs bearing short claws (Plate - 47, Figs.5-5e).

II. QUANTITATIVE ANALYSIS

(1) Analysis of nutrients present in soil samples (both Experimental and Control groups)

Results of quantitative analysis disclosed that the feeding activity of oribatid mites on the mangrove litter resulted in an increase in the concentration of nutrients like Nitrogen, Phosphorous and Potassium (N,P,K) 4.384 ± 0.496 ppm, 25 ± 2.78 ppm and 11.218 ± 0.606 ppm respectively. Statistical analysis of the data obtained on quantitative studies on the concentration of N, P, K in experimental and control soil samples following unpaired student 't' test are presented in (Table. 6). Data were analyzed using statistical package and expressed as Mean $\pm$ Standard Deviation (SD). Two-tailed unpaired t-test were done and the values are set significant at $P < 0.05$ and asterisks (*) denotes significant against the control group. As shown in the table.6, the data on nutrient analysis were found significant ($P < 0.05$) thereby confirming that the oribatid feeding activity would enhance the nutrient status of mangrove soils.

III. POST EMBRYONIC DEVELOPMENTAL STUDIES:

A. Postembryonic Development of *H. epimeratus* sp.nov. (Plate-48; Plate-49, Figs. 1-8)

1. Oviposition, Incubation and Hatching

The adult males (Plate-49, Fig.1) deposited stalked spermatophores on and around the litter residues of *A. marina* and *A.ilicifolius*, on the culture base, on surfaces of dead/ decaying leaves and so on. The spermatophores laid in the culture cell looked like dew drops having globular shining heads on thin, erect stalks (Plate-49, Fig.2). Gravid females of *H. epimeratus* laid eggs singly in concealed habitats like the small crevices on bark, small twigs and under litter particles, which were offered as feeding substrates within the culture cells. Quite often, eggs were observed in between grains of sand and under the litter residues offered as food at the base of the culture cells. Eggs were very small, transparent and milky- white in colour. During progressive days of incubation, the colour of eggs got changed from white to pale brown and later to brown in colour prior to hatching. The initiation of the hatching was marked by gradual weakening of the outer membrane and appearance of a longitudinal slit along the egg pole. The wriggling and threshing movements of the larva inside the eggshell helped in widening of the slit for easy emergence.

2. Duration of Life Stages (Table.7; Plate-48)

The newly hatched larva was very delicate, pale brown in colour and with a wrinkled, soft, plicate integument. It could be easily distinguished by its hexapodous nature. Immediately after hatching, the larva remained inactive for 15-20 minutes and tried to hide itself always under the litter residues (decayed leaf of *A. marina*) and small cracks in the culture cells. Later it initiated feeding on very small litter residues scattered over the grains of sand within the culture cells. The active feeding period of larva extended for 5-6 days and then it became sluggish, almost stopped feeding its body became slightly swollen and it entered into a period of physiological inactive phase called the 1st quiescent phase/ stage. This dormant period lasted for 4–5 days and the end of which was marked by the moulting process marked by the appearance of prosterolateral slit on either sides of the notogaster. The protonymph emerged subsequent to moulting of larva was an octapod, slightly larger than the larva and transparent with a wrinkled integument. The protonymph remained active for 10 – 13 days by feeding on the litter residues and then became quiescent (2nd quiescent stage) for 5 – 6 days and subsequently moulted into the succeeding nymphal stage called the deutonymph. The deutonymph was comparatively larger in size and more active than the previous stage. The deutonymphs were found aggregated onto the droplets of saline water adhered to the walls/lids of culture cells. The colour of the deutonymph gradually got changed from pale to brown. After an

active feeding period of 14 – 19 days, it entered in to a period of quiescence (3rd quiescent stage), which lasted for 4 – 7 days. On subsequent moulting, the tritonymph which was the largest among the nymphal instars and was more sclerotized. The active feeding period of the tritonymph lasted for 15 – 19 days. Then the tritonymph passed through the 4th quiescent phase of 5 – 6 days and underwent the final moulting to give rise to the adult individual. The adult mites were densely dark brown in colour and they preferred to feed on the litter residues of dead leaves of *A. marina* and *A. ilicifolius*. Thus during the present study, the life cycle of *H. epimeratus* was found to complete within 82 – 102 days, under laboratory conditions of 27±2°C and 79± 2% RH. The newly emerged adult female initiated oviposition after 17-21 days of emergence. Therefore, the total duration of F₁ generation of *H.epimeratus* sp.nov. was found ranging from 99- 123days.

Morphological Description of Life Stages of *H.epimeratus* gen.nov. sp.nov.

(Table.8-12; Plate- 49, Figs. 1-8; Plates-50&51, Figs. 1-4)

EGG

(Plate-49; Fig.3)

Measurements : Length: 107 -111 µm

Width: 56 - 59 µm

Eggs were oval in appearance, white and transparent, glittering with porose surface when viewed under higher magnification.

LARVA

(Plate-49, Fig. 4)

Measurements :Length: 125 -127 μ m

Width: 87 – 91 μ m

The newly emerged larva could be differentiated easily based on the presence of 3 pairs of legs, small sized body, creamy white colouration and the translucent nature of the body.

Dorsal Region (Plate-50, Fig.1)

Prodorsum

Prodorsum triangular in appearance and produced in to conical rostrum, prodorsal surface ornamented with small cerotegumental granules; setae *ro*, *in* and *le* almost equal in size while setae *in* and *ex* minute; bothridial cups opened laterally from which sprouts the short stalk of the sensillus, the head of the latter bears small spines.

Notogaster

Notogaster more or less oval in appearance with a wrinkled integument, 11 pairs of setae (*c*₁, *c*₂, *c*₃, *da*, *dm*, *dp*, *la*, *lm*, *lp*, *h*₁, *h*₂, *h*₃) inserted on the notogaster, all minute; integument of notogaster ornamented with small granules; centrodorsal plate with transverse ridges, running upto posterior margin of the notogaster.

Ventral Region (Plate-50, Fig.2)

Infracapitulum diarthric type, seta *h* detected, setae *m* and *a* absent; Ventral integument finely granular; epimeral setal formula 2-1-1, epimeral surface granular; claspere's organ globular; genital, aggenital, anal and adanal setae not developed.

Legs

Legs 3 pairs, all monodactylous, claws hook like.

PROTONYMPH**(Plate -49, Fig. 5)**

Protonymphs could be distinguished from the larval stage by the possession of 4 pairs of legs, slightly larger size of body, presence of a pair of genital suckers and pale brown colouration of the body.

Measurements : Length: 146 -150 μm

Width: 97 - 102 μm

Dorsal Region (Plate-50, Fig.3)**Prodorsum**

Rostrum rounded; prodorsal cerotegument granular; lamellae visible as narrow lines, seta *le* small, inserted at the tip of the lamella; bothridial cups

well developed, sensilus with a spined head, the stalk of sensillus relatively longer than that of the larva.

Notogaster

Notogaster bears 15 pairs of minute setae ($c_1, c_2, c_3, da, dm, dp, la, lm, lp, h_1, h_2, h_3, p_1, p_2, p_3$), setae *la, lm*, and *lp* located at the latero-posterior margins of centrodorsal plate; integument of anterior notogastral region wrinkled (folded); centrodorsal plate surface finely granular.

Ventral Region (Plate-50, Fig.4)

Infracapitulum oval shaped, bears 3pairs of setae, *h, m* and *a*, all thin and smooth; seta *h* longer than other setae; epimeral setation 3-1-2-1, setae *1c, 3b* and *4a* newly added at this stage), lateral epimeral surface bears dense granules; genital plates developed with a pair of small setae (g_1); anal and adanal setae not developed; anogenital integument wrinkled (folded).

Legs

Legs 4 pairs, all monodactylous, with hooked claws.

DEUTONYMPH

(Plate -49, Fig. 7)

Deutonymph was easily distinguishable from the preceding nymphal stage by its increased larger size, brown colour of the integument and presence of 2 pairs of genital suckers.

Measurements : Length: 179 -187 μm
Width: 108 -112 μm

Dorsal Region (Plate-51, Fig.1)

Prodorsum

Prodorsum conical in appearance and extended anteriorly into a rounded rostrum; prodorsal setae simple and smooth; lamellae well developed and connected by a narrow translamellar line; entire prodorsal surface ornamented with conspicuous cerotegumental granules.

Notogaster

The shape of the notogaster resembled that of the previous instar, 15 pair of minute setae inserted on the notogaster as shown in (Plate-51, Fig.1); the shape and size of notogastral setae resembled those of the protonymph; median part of the notogastral surface less granulated in appearance.

Ventral Region (Plate-51, Fig.2)

Infracapitulum with 3 pairs of setae *h*, *m*, and *a*, all setae thin and smooth; Epimeral surface granulated, epimeral setal formula 3-1-2-2, all setae smooth, minute; genital setae 2 pairs (g_1 - g_2); anal setae vestigial; 1 pair of aggenital setae (ag_1) present; 2 pairs of adanal setae (ad_1 , ad_2) present; adanal lyrifissure (*iad*) located at the anterior margin of the anal plate.

Legs

All legs monodactylous with hooked claws.

TRITONYMPH

(Plate 49; Fig.8)

Tritonymphs could be differentiated from the deutonymphal stage by its larger size, brown colour of the integument and presence of 3 pairs of genital suckers.

Measurements :Length: 212 -217 μm

Width: 129 - 137 μm

Dorsal Region (Plate-51, Fig.3)

Prodorsum

Rostrum rounded; all prodorsal setae well developed; lamellar ridges well developed and connected by a conspicuous translamella; sensillus with a prominent clavate, finely barbed head; prodorsal integument densely granulated.

Notogaster

Notogaster with 15 pairs of setae, arranged as shown in (Plate-51, Fig.3), all setae much longer than from previous stage; notogastral integument

marked with small circular depressions, arranged in a tuberculated pattern; antero- lateral sides of the notogaster provided with numerous folds.

Ventral Region (Plate-51, Fig.4)

Infracapitulum diarthric type, bearing 3 pairs of simple, smooth setae *h*, *m* and *a*; Epimeral surface ornamented with dense granulation; epimeral setal formula 3-1-2-2, all setae smooth, minute; genital setae 4 pairs (*g*₁-*g*₄); aggenital setae 1 pair; anal setae 2 (*an*₁ & *an*₂) pairs, 3 pairs of adanal setae (*ad*₁-*ad*₃) present; fissure *iad* located at the anterior margin of the anal plate.

Legs

All legs monodactylous

Common Features of the Juvenile Stages of Intertidal Oribatid Mites **(Plate-52, Figs.1-6)**

The larva and all juveniles of the intertidal oribatid mites are generally called as “Apheredermous” which means that they are plicate and soft bodied. A detailed study on the morphological characters of the juvenile instars of *H. epimeratus* disclosed that the juvenile stages share certain common features like the possession of a rounded rostrum , triangular prodorsum, finely granulated nature of the anterior region of the body , short and simple nature of prodorsal setae including setae *ex* and *in*, cup like laterally opened bothridia, presence of numerous pores of the underlying fine tracheal tubes/

channels at the median prodorsal border, possession of monodactylous legs bearing hook-like claws etc. Hysterosomal lyrifissures were not visible in any of the juvenile stages. Centrodorsal plate finely granular and some slightly large sized granules present in folds, furrows.

B. Postembryonic Development of *A. clavata* (Märkel, 1964) on dead Pneumatophores and Filamentous Green Alga, *Microspora* sp. (Plate-53; Plate-54, Figs.1-8)

3. Larviposition

An interesting observation made on the life history of *A. clavata* was the absence of oviposition within the culture cells, unlike the other species of oribatid mites. The gravid females carried oval-shaped eggs inside their body, which contained embryos which gradually developed into pre-larva. After 14-18 days of development within the body cavity of the female mite, larviposition was observed, which resulted in the birth of a fully developed six-legged larva.

4. Duration of Life Stages (Table.13; Plate-53)

The newly emerged larva was very delicate in nature and remained inactive for about 10 minutes. Then it crawled on the substratum, and started wandering inside the culture cell in search of food. It showed preference to feed on both fresh and dead algal filaments of *Microspora* sp. and the cortex

tissue of the pneumatophore of *A. marina*. After 5-6 days of active feeding, the larva became completely immobile and enlarged their body size and moved into 1st quiescent stage. The larval quiescence extended for 3-5 days and which was ended by the moulting process and moulted into protonymph stage. The active period of the protonymph lasted for 3-4 days and then it retarded its feeding activity, became sluggish, transformed its body into a turgid condition and entered into the 2nd quiescent phase of 5-6 days duration. On subsequent moulting, the deutonymph emerged and the latter was a voracious feeder on the various food items provided. Intensive feeding was evident through the formation of food boli within the digestive tract and which could be clearly perceived through the transparent body of the deutonymph. The pure white colour of the deutonymph later got changed to off-white. After an active feeding period of 3-5 days, it entered into the 3rd quiescent phase of 6-9 days duration. The 3rd quiescent stage moulted into the transparent tritonymphal stage and which was recognized as the largest among all other nymphal stages. The tritonymph exhibited active feeding on the dead pneumatophores for a period of 10-11 days and then it passed through the 4th and final quiescent stage of 7-9 days duration and moulted into the light brown coloured adult. Under laboratory conditions of $27 \pm 2^\circ\text{C}$ and $79 \pm 2\%$ RH, *A. clavata* completed its development from egg to adult within 61-72 days. The newly emerged females produced eggs after 8-11 days of their emergence, but these eggs remained inside their body cavity and were not

deposited, but such gravid females showed larviposition, giving birth to fully mature larvae.

Morphological Description of Life Stages of *A. clavata* (Märkel, 1964)
(Table.14-18; Plate-54, Figs.1-8; Plate-55, Figs.1-4)

EGG

(Plate- 54; Figs.1-1a)

Measurements : Length: 173-185 μm
Width: 57 - 62 μm

Eggs were small, oval, white, transparent and found inside the body of the adult female.

PRELARVA

(Plate -54; Fig.2)

Detected inside the body of weakly sclerotized females. Prelarva more or less oval in appearance, enclosed inside the eggshell and found to possess 3 pairs of monodactylous legs.

LARVA

(Plate -54; Fig.3)

The larva could be easily distinguished by the possession of 3 pairs of legs. The cuticle of the larva was weakly sclerotized, colourless and smooth.

The rutella of subcapitulum and its digits showed very little sclerotization and appeared as light brown coloured.

Measurements : Length: 173-186 μm
Width: 74 – 82 μm

Dorsal Region (Plate-55, Fig.1)

Prodorsum

Prodorsum relatively short with a broadly round rostrum; setae *ro*, *le* and *in* long, setiform and smooth; seta *ro* inserted at the tip of rostrum, seta *le* inserted anteromedial to seta *in*; length of setae varies in the sequence *in*>*ro*>*le*; bothridial cups not well developed; seta *ex* inconspicuous.

Notogaster

Notogaster with 10 pairs of setae (*c*₁, *c*₂, *c*₃, *c*_p, *d*₁, *d*₂, *e*₁, *e*₂, *h*₁ & *h*₂) setae *ps*₁, *ps*₂ & *ps*₃ absent.

Ventral region:

Infracapitulum stenarthric, setae *h*, *m*, *a* setiform, smooth, setae *m* little shorter than the other; epimeres with paired, smooth plates having weakly defined borders, Epimeral setal formula 3-1-2, all setae setiform, smooth, with flagellate tip; genital, aggenital, anal and adanal setae not developed.

Legs

All legs monodactylous.

PROTONYMPH (Plate- 54; Figs.3b,4a&b)

Protonymph appears larger than the larva and easily identified by the presence of 4 pairs of legs. Body almost cylindrical in appearance, and not ptychoid. The protonymph possesses 1 pair of genital sucker.

Measurements : Length: 270 -292 μm
Width: 119 - 128 μm

Dorsal Region (Plate-55, Fig.2)

Prodorsum

Prodorsum comparatively short and reaching about half the length of the notogaster; rostrum widely rounded, all prodorsal setae, smooth with flagellate tip; length of setae *in>ro> le*; bothridium and setae *ex* present.

Notogaster

Notogastral surface smooth, 14 pairs of smooth setae inserted on the notogaster as shown in (Plate-55, Fig.2) , setae h_3, ps_1, ps_2 and ps_3 newly added in this stage, setae e_1, h_1 longest, other setae much shorter; distinct simple transverse linear groove (ar_3) present, posterior to setae of *e*- series.

Ventral region

Infracapitulum stenarthric, setae *h*, *m*, *a* setiform and smooth; Epimeral plates with weakly defined borders; epimeral setal formula 3-1-2-1, all setae setiform, smooth, longest with flagellate tip, 1 pair of genital setae and one pair of genital suckers present; anal and adanal setae not developed.

DEUTONYMPH**(Plate-54; Figs.5a&b)**

The deutonymph was recognized easily based on the presence of 2 pairs of genital suckers and relatively larger size of the body than that of the previous stage.

Measurements : Length: 306 -314 µm
Width: 146 - 160 µm

Dorsal Region (Plate-55, Fig.3)**Prodorsum**

Prodorsal integument smooth; rostrum elongated; prodorsal setae smooth and of varying size, seta *in* the longest, length of prodorsal hairs varies in the order *in>le>ro*; seta *ex* conspicuous; sensillus clavate; bothridial cups well developed.

Notogaster

Notogastral integument delicate, smooth; number of notogastral setae same as that of the protonymphal stage, setae e_1 , e_2 , h_1 - h_3 and ad_1 - ad_3 long with flagellate tip; lyrifissures ia , im and ip clearly visible in lateral view.

Ventral region

Infracapitulum stenarthric type, bearing 3 pairs of simple, smooth setae; Epimeral setal formula 3-1-3-2, all setae smooth and setiform; genital plates with 4 pairs of simple, minute genital setae (g_1 - g_4) and 2 pairs of genital suckers; 2 pairs of minute aggenital setae present on the lateral margins of the aggenital plates; 3 pairs of long, smooth, adanal setae (ad_1 - ad_3) present; anal setae absent.

TRITONYMPH

(Plate-54; Figs.6a&b)

Body of the tritonymph off-white in colour. Tritonymph forms the largest among the juvenile stages and could be easily distinguishable based on the larger size, presence of 3 pairs of genital suckers and the off-white colouration. Tip of the rostrum sclerotized with light brown colouration.

Measurements	: Length: 327 -340µm
	Width: 210 - 224 µm

Dorsal Region (Plate-55, Fig.4)**Prodorsum**

Prodorsum produced in to an elongated rostrum; prodorsal surface ornamented with very fine granules, prodorsal integument pale brown in colour; carinae developed as narrow line below the bothridium; all prodorsal setae well developed, smooth, setiform with flagellate tips.

Notogaster

Notogastral setae 14 pairs, setae of series e_1 , h_1 and ps_1 longer than the rest; notogastral integument smooth and delicate.

Ventral Region

Infracapitulum stenarthric type with 3 pairs of simple, smooth setae; Epimeral setal formula 3-1-3-3, all setae setiform, smooth, setae $1b$, $3c$ and $4c$ equal in size and with flagellate tip; anogenital plates conspicuous; 6 pairs of minute, simple genital setae (g_1 - g_6) present; 3 pairs of adanal and 3 pairs of anal setae present on the fused ano-adanal plates, seta an_3 small, located near the interlocking triangle area.

Legs

All legs monodactylous.

Mangroves constitute one of the most productive ecosystems in tropical and sub tropical countries in the world, providing shelter cum feeding and breeding grounds for the terrestrial and aquatic invertebrate and vertebrate fauna. Being the transition zones which separate the terrestrial life from the marine forms, mangroves induce some physiologically stressful environments to the flora and fauna which in turn would develop adaptive strategies to tolerate desiccation, heat, cold, salinity etc. and frequently to overcome actual anoxic conditions. Mangrove vegetation provides the food and shelter for the survival and replenishment of millions of above ground and underground fauna, of which the latter is represented mainly by the microarthropods. Among the microarthropods, the Acari or the mites represent the most diverse and numerically abundant group of soil ecosystem (Norton, 1994). The soil mites to a large extent is represented by the group ‘Oribatida’ or the oribatid mites which are very ancient in origin, with their evolutionary history dating back to some 410 million years ago when expansion of early Devonian terrestrial ecosystems occurred (Norton *et al.*, 1988; Feng *et al.*, 2014).

Oribatid mites are commonly called as the “moss mites or beetle mites” and are known to inhabit a wide variety of microhabitats available in terrestrial ecosystems like the soil, forest floors, pockets of litter accumulation, humus layers, lichens, moss, algae, fungal cushions and in the bark of trees, in the nests of birds and mammals, in suspended soils etc. They are present in abundance in arboreal ecosystems like the foliage of trees, canopies etc. and are known to occupy aquatic and semi-aquatic ecosystems, including the intertidal and coastal areas. Being the principal component of the detritivorous food chain of the terrestrial ecosystem, these mites play vital roles in triggering the processes of organic decomposition and associated humification and nutrient cycling, thereby leading to enhancement of soil fertility and productivity. Additionally, they have been immensely proved to serve extremely beneficial roles in nature like the bioindication of soil conditions including radioactive pollution, bioremediation, biological control of pests and weeds, forensic science to monitor post mortem interval and so on. Despite such overwhelming beneficial roles that influence human life either directly or indirectly, the bewildering diversity and astonishing behavioural and biological attributes are very rarely explored even today. Though India is blessed with vast stretches of mangrove ecosystems, which exert tremendous impact on the productivity of our ecosystem and conservation of our biodiversity, no earnest attempts have been made so far to explore the faunal diversity of an extremely beneficial arthropod group like

the oribatid mites inhabiting our mangrove ecosystems. This prompted to undertake the present Ph.D programme as an initial step, to record the existing faunal composition and species diversity of oribatid mites inhabiting the mangrove ecosystems of North Kerala, to study the morphological and ecological parameters of these mites, to understand the feeding and breeding habits of a few selected common species of local importance and also to trace the probable role they play in their surrounding environment .

In the present study, a qualitative assessment of the faunal diversity of oribatid mites inhabiting 15 various mangrove ecosystems distributed over 4 districts of North Kerala viz. Malappuram, Kozhikode, Kannur and Kasaragod was made, based on field sampling of materials like the mangrove soils/, litter/ pneumatophores/dead twigs and barks for the extraction of mites. Random sampling method was adopted during the study at different time intervals depending up on the tidal rhythms in specific mangrove habitats Sites enriched with true and associate mangrove vegetation such as littoral soils, coastal fringes, riverbanks, river mouths, algal growth on intertidal rocks etc. were considered for sampling of oribatid mites. The results of faunistic surveys enabled to recover 23 species of oribatid mites belonging to 21 genera, 16 families and 10 Superfamilies. Of these, one genus viz. *Holocarinozetes*, gen.nov., and 6 species were new to science and 14 species were new records from the mangroves of India. The present recovery of a new genus, 6 new species and several new records of oribatid mites is a clear

indication that our mangrove ecosystems are rich in the fauna of these mites and more extensive surveys are warranted to unravel the rich diversity of these mites comprising more number of novel taxa.

During the present study, the species composition and distribution pattern of the various species of oribatid mites were found varied depending on the vegetational, climatic and topographic peculiarities as well as the edaphic characteristics of the sites screened. This observation is in agreement with the earlier finding that the structure of oribatid community exhibits a close correlation with the type of habitat (Maraun and Scheu, 2000; Karasawa and Hijii, 2004b). Number of oribatid species was found harbored by the mangrove sites distributed over the Malappuram Dt. and a total of 8 species viz. *H.hirsutus*, *H.(H.) vitrina*, *L.(L.) molecula*, *L.(P.) bengalensis*, *S.(S.)praeincisus interruptus*, *P.(P.) capucinus*, *I.(I.) punctulatus* and *T.(R.) ovulum ovulum* were recovered. Of the various sites surveyed in this district, site-I was characterized by mixed true and associate mangrove vegetation and which supported 5 species, representing 4 genera, 4 families and 3 superfamilies. Probably, the diverse types of decaying litter residues of mangrove vegetation would have set favorable conditions for the dominance of litter dwelling oribatid species. Availability of diverse feeding substrates in different stages of decomposition would exert a positive impact on the numerical abundance of these mites (Ramani and Haq, 2001, Franklin *et al*, 2004) as observed during the current study. These mites occur as dominant

forms in litter accumulations in forest floors (Ramani and Haq, 1991b; Julie and Ramani, 2008), and also in various soil profiles, in surface litter, low-growing herbs, shrubs, bark, twigs and leaves of trees, the barks, semi-aquatic and coastal habitats (Behan-Pelletier, 1999; Norton, 1990; Weigmann, 2012). Despite the above known habitats, several oribatid mites have been reported to extend their distribution to arboreal habitats (Aoki, 1980; Ramani and Haq, 1988; Behan-Pelletier and Walter, 2000), littoral environments (Pugh *et al.*, 1990, Luxton, 1992; Pfungstl, 2013a), at the edges of lakes and rivers, especially in Sphagnum and other mosses (Seniczak *et al.* 2007, 2009c; Seniczak & Seniczak 2008a, 2009a) and the mangrove and bank forests (Karasawa and Hijii, 2004b; Julie and Ramani, 2008; Julie *et al.*, 2013).

The collection sites selected for the present study showed their unique intertidal characteristics with the presence of true and associate mangrove species. Two sites viz. Brahmasampadam (BRSPM) and Olipramkadavu (OPKDV) in the Malappuram district and 5 sites viz. Kadalundi-Vallikkunnu community reserve mangrove –I (KVCR-I), Kadalundi-Vallikkunnu community reserve mangrove –II, Kottakkadavu (KTKDV), Kallai (KLAI) and Mankavu (MNKV) in the Kozhikode district were screened to explore the species composition of 19 oribatid mite species. viz. *C.(C.) reticulatus*, *A.unilateralis*, *H.aureus* sp.nov., *H. hirsutus*, *J.(J.) porosus*, *A.clavata*, *H. (H.) vitrina*, *A. arboreus*, *C.(K.) penicillus*, *H. epimeratus* sp.nov., *L.(L.)molecula*, *P. kadalundiensis* sp.nov, *S.(S.) malabarica*, *S.(S.) praeincisus interruptus*, *P.*

(*P.*) *trifolius* sp.nov, *I.(I.) punctulatus*, *G.(G.) paragibbula*, *T.(R.) nortoni* sp.nov., *T.(R.) ovulum ovulum*.

Among the 7 sites in the Kannur district screened, the characteristic true and associate mangrove ecosystems of Kannur district support species composition of 15 oribatid mites viz. *A. unilateralis*, *H. hirsutus*, *J.(J.) porosus*, *A.clavata*, *H.(H.) vitrina*, *A.longisetosus*, *C.(K.)penicillus*, *S. mangrovius* sp.nov, *L.(L.)molecula*, *L.(P.)bengalensis*,*S.(S.) praeincisus interruptus*, *P.(P.) capucinus*, *I.(I.) punctulatus*, *G.(G.) paragibbula* and *T.(R.) ovulum ovulum*.

Characteristic mangrove ecosystem at a single site in the Kasaragod district supports 5 species of oribatids viz. *C.(C.) reticulatus*, *A.clavata*, *A.longisetosus*, *L.(L.)molecula* and *I.(I.) punctulatus*

The faunal diversity of oribatid mites recovered from the 5 sites of the Kozhikode district comprised of 19 species belonging to 17 genera, 13 families and 10 superfamilies. The selected 2 sites viz. Kadalundi-Vallikkunnu community reserve mangrove–I (KVCR-I) and Kadalundi-Vallikkunnu community reserve mangrove –II (sites 3 &4) were found enriched with true and associated mangroves and other herbs and shrubs which formed the major soil littoral components/ ingredients. The above two sites were proved to have rich species diversity by supporting 14 species, representing 14 genera, 13 families and 10 superfamilies, including one new

genus, and 4 new species. The species *Holocarinozetes* Gen. nov., *H. epimeratus* sp. nov. (Fortuyniidae), *Phauloppia kadalundiensis* sp. nov. (Oribatulidae), *Protoripoda (P.) trifolius* sp. nov. were found associated with algal cushions, pneumatophores and dead decaying twigs of true and associate mangroves. The availability of most preferred food items (Pfingstl, 2013c) and specific microhabitat (Karasawa and Hijii, 2004a&b), offered favourable conditions for the survival of the maximum species of oribatids in this site. Mangrove pneumatophores, algae and barnacles would provide ideal surfaces for the attachment of sedimentary biota, especially for the oribatid mites (Luxton, 1990b; Procheş *et al.* 2001; Proches and Marshall, 2002a; Marshall and Pugh, 2002). Species like *A. arboreus* and *C. (K.) penicillus* colonized strictly on the tidal debris left after high tide. Tidal debris has been reported as a common habitat for littoral mites (Luxton, 1990a). Many investigators have proved that a positive correlation of oribatids with the association and restriction in coastal ecosystems, tidal debris, littoral fringes, salt marshes, intertidal and supralittoral zones (Luxton, 1964; Schuster, 1979; Talker *et al.*, 1981; Proches and Marshall, 2001).

During the present study, though species diversity was observed in the oribatid mites of mangrove ecosystem as evident through the recovery of 23 species, the numerical density of individual species was found comparatively low than the related soil dwelling forms. The mangrove forests though have been reported as highly productive ecosystems, possess low species richness

(Duke *et al.* 1998). The species richness and diversity of oribatid mites were already reported to be comparatively very low in mangrove soils of Kerala (Julie and Ramani, 2007; Julie *et al.*, 2013). The oribatids inhabiting the littoral and arboreal environments of marine and intertidal habitats generally possess some specific adaptive structural modifications like the thick cerotegument covering on body, well developed tarsal claws with monodactylous or tridactylous condition and reduced length of sensilli (Karasawa and Hijii, 2004a). In the present study similar structural modifications could be met with in several species like, *H. epimeratus*, *S. mangrovius*, *P.(P.) trifolius*, *P.kadalundiensis* and *C.(K.) penicillus* etc. The littoral and arboreal forms of oribatids collected from sites 3 &4 of the Kozhikode Dt. possessed morphological adaptations like longer claws on legs, which were either monodactylous or tridactylous. Such modifications in the claw morphology might be interpreted as an adaptation to give firm grip on plants during unpredictable environmental changes like wind and rain for arboreal oribatids and tidal flooding for littoral forms. (Behan-Pelletier and Walter, 2000; Karasawa and Hijii, 2004a). Oribatid species dwelling in littoral environments are reported to exhibit activities, which could be correlated with the tidal rhythms (Schulte, 1976; Weigmann and Schulte, 1979; Ernst *et al.* 1993).

The results of the present study enabled to recover typical small sized “thalassobiont oribatids”(Schuster, 1977; Krisper and Schuster, 2008; Pfingstl

and Schuster, 2014) intertidal oribatid species like *H. epimeratus* sp.nov. (Fortuyniidae) of the superfamily Ameronothroidea from the upper eulittoral zone of Site 4, where the litter types were predominated by those of mangrove plants like *A.marina* and *A. ilicifolius* which periodically were inundated by seawater. The mangrove fauna in general are subjected to rhythmic tidal inundations, periodic washing of tidal currents and some other physiological stress like high salinity conditions, reduced oxygen intake etc. Accordingly, population dynamics and cuticular structure of such oribatid mites also were reported to get necessarily modified with respect to their reaction to the effects of tidal rhythms/ flood cycle (Franklin *et al*, 1997; Adis and Junk, 2002; Pfingstl, 2013a.). Such oribatid mites respire through a series of cuticular respiratory structures called the “van der Hammen’s organ,” (Van der Hammen, 1963; Crowe and Magnus 1974; Krantz and Baker, 1982; Pugh *et al.* 1987; Crisper and Schuster, 2008; Pfingstl and Krisper, 2014). The present study also disclosed the possession of van der Hammen’s organ in species like *H.epimeratus* thereby assigning them to the category of truly intertidal oribatids and thus supporting the earlier inclusion of these mites in the thalassobiont category. Thus, the results of the study helped to add more number of oribatids to the existing list of intertidal mites.

The present study enabled to record mangrove associated oribatids with small sized body plan in species like, *S. mangroviussp.nov* and *H. epimeratusgen.nov. sp.nov.* All the littoral inhabiting oribatids having small

size it might be considered as an advantage for finding more suitable habitat space for feeding or avoid predators (Walter & Norton 1984). Many aquatic species of the family Hydrozetidae and Limnozetestidae were reported as alive or dead on still as well as flowing waters (Krantz and Baker, 1982 and Schatz and Behan-Pelletier, 2008). These species have the potential to inhabit in freshwater habitats also including the lentic (pools, ponds, lakes, swamps) or flowing waters (springs, rivers and streams), mainly on-submerged plants (Schatz & Behan-Pelletier 2008). In the current study, the species viz. *P.(P.)trifoliatus* and euphthiracarid mite *A. clavata* could be recovered from the submerged plant parts of *D. trifoliata* and *A. marina* respectively.

Results of field sampling disclosed the close association of certain oribatid species collected from sites 3 and 4 with the dead/ decaying parts of true mangroves and mangrove associates. Such species include *A. clavata* (associated with algal cushions and barks of dead pneumatophores of *A. marina*), *P. kadalundiensis* sp.nov.(associated with dead leaves of *A. officinalis*), *P. (P.) trifoliatus* sp.nov. associated with dead barks of *D.trifoliata*. Quite often, such close association was found supported by the possession of specific morphological features by the species like the possession of trodactylous condition on legs, nature of claws etc. This was found true in species like *S. (S.) malabarica* recovered from decaying spikelets of *M. javanicus* growing in site 3. The tridactylous legs of the species would be advantageous to the species for survival in site 3, which is

situated very near to the shore of the Arabian Sea and is constantly exposed to strong unpredictable wind. This observation supports the earlier view that the structure and special microhabitat diversity are strongly associated with the diversity of oribatid mites (Walter and Behan-Pelletier, 1993; Walter *et al* 1994; Proctor *et al.* 2002; Lindo and Winchester, 2006; Fischer *et al*, 2010).

Riverine environments often were found to support new species of oribatid mites (Mahunka, 2010; Ermilov *et al.* 2013). This was confirmed through the results of the present study also by recovering a total of 8 species under 7 genera, 5 families and 3 superfamilies from sites 5-7. All these sites were located at the basins of river, bordered by small mangrove patches dominated by *A. marina* and *A. ilicifolius*. Members of some oribatids extend their distribution along the basins of litter accumulated areas from riverine and fresh water habitats (Schatz and Behan- Pelletier, 2008; Bayartogtokh and Chatterjee 2010; and Weigmann, 2012). Results of the present study support this by recording the preference of 3 Lohmanniid members viz. *A. unilateralis*, *J. (J.) porous* and 1 new species *H. aureus* sp. nov. recovered from the sandy, mangrove littorals of sites 5-7 to the moist habitats like the edges of lakes, mangroves, sandy soils and threads of green algae on the soil surface of Islands (Hammer, 1973; Schatz, 1994; Schatz and Schuster 2012).

Oribatid mites in general are known to be adapted to inhabit varying habitats in their environment and many species thrive successfully in arboreal

ecosystems including foliage, canopies, barks, small twigs, branches (Ramani and Haq, 1988; Behan and Walter, 2000; Karasawa and Hijii, 2005; Karasawa and Behan, 2007; Lindo and Winchester 2008; Sobek *et al.* 2008). In the present study, certain species exhibited microhabitat specificity while some others showed wide distribution trend. Of the 16 species collected from the sites 8-15, members of Lohmanniidae and Haplozetidae showed wide distribution trend in varying microhabitats like different types of mangrove soils, littorals, including decomposing leaves, barks of mangrove plants etc. The species, *P.(P.) capucinus* was found to confine its distribution on the litter of littorals of the mangrove plant, *A. marina* in truly intertidal mangrove habitats. Such restricted distribution trend on decaying leaves of the true mangrove plant, *A. marina* (Hammer 1973) or litter of shrub mangroves like *R. mangle* and *A. nitida* has been reported earlier in oribatid mites (Garcia-Gomez *et al.* 2014). The species of the intertidal family Selenoribatidae viz. *S. mangrovius* sp. nov., could be recorded from the algae growing on mangrove pneumatophores and mangrove litter samples. The family Selenoribatidae represents a group of littoral oribatids found attached to the roots of the black mangrove, *A. germinans* during low tides (Pfingstl, 2013a,b) and the genus *Selenoribates* comprises true intertidal oribatids which inhabit on intertidal algae, growing on the rocky as well as sandy substrates (Pfingstl and Schuster, 2013a). The recovery of a new member of the above genus during the current study, viz. *S. mangrovius* sp.nov., from the algae growing on

pneumatophores indicates the possible phycophagous trend of members of *Selenoribates*.

In the present study, attempts were also made to record data on the feeding habits of selected mangrove dwelling oribatid mites. The Euphthiracarid species, *A.clavata* exhibited a close association with the epiphytic alga, *Microspora* sp. growing on the barks and pneumatophores of the true mangrove plant, *A. marina*. All the life stages viz. the larva, 3 nymphal stages (Proto-, deuto-, trito- nymph) and their respective dormant (quiescent phase) stages also were detected on the green algal cushions. Intensive feeding by the species was evident through tunneling activity and production of large amount of fecal pellets on the algal cushions and bark and this supports the general feeding nature of phiracarid and euphthiracarid species which normally make burrows and feed on epidermis and internal tissues (Jacot, 1939; Murphy, 1952,1953), and also produce tunnels on their feeding substrates (Wallwork, 1958, 1976b; Hayes, 1963; Pande and Berthet, 1973; Luxton 1984; Hagvår, 1998), irrespective of habitat variation. The members of the intertidal genera like *Alismobates*, *Carinozetes* and *Fortuynia* were known to feed exclusively on intertidal red algae, *Bostrychia tenella*, *Herposiphonia secunda*, and *Gardnerula* sp. respectively (Pfingstl, 2013c). The present study also disclosed algal feeding in *A. clavata*, by recording the feeding activity of all the life stages of the species on *Microspora* sp. The nymphal stages of *A. clavata* showed aggregation on both the fresh and

decaying filaments of *Microspora* sp., thereby establishing the latter as the natural diet of the species. This was further confirmed through the results of food choice experiments also, which revealed the feeding preference of the species to the pneumatophores and algal filaments, moistened with saline water. Progressive feeding by the active nymphal stages of the species resulted in the consumption of the gas- filled aerenchymatous tissue also which in turn led to the production of light coloured faecal pellets at different regions of the feeding substratum.

The number of individual mites present on a particular type of food and production of faecal pellets together could be considered as the parameters for the assessment of feeding rate in phthiracarid mites (Hayes, 1963). The palatability of litter to oribatid mites was often found often by its chemical and physical properties (Jacot, 1939; Kuhnelt, 1948; and Murphy, 1953). A similar impact was produced by the moisture content of algae-covered bark substrates also (Smrz, 2001). Results of feeding experiments performed during the current study showed the aggregation of all life stages on the dead moistened pneumatophores in culture cells, especially on very soft/delicate aerenchymatous tissues and the hard tissues especially the epidermis and pericycle were found excluded. The nymphal stages showed the presence of green and brown coloured faecal pellets inside their digestive tracts thereby confirming the preferential feeding on different diets based on their palatability.

In the present study, *I. (I.) punctulatus* showed preference to feed on the dead/ decayed parts of *D. trifoliata*, which were chopped into small fragments by the species. Intensive feeding activity of the various life stages resulted in the formation of small feeding channels, which often were found filled with large amount of black coloured fecal pellets. This finding supports the earlier observation on other soil dwelling oribatids, which produced feeding cavities/ tunnels on woody elements and such cavities were filled with fecal pellets also (Wallwork 1958; Pande and Berthet, 1973). This has been recognized as a common function of soil fauna, especially that of the oribatid mites which enhance the process of organic decomposition, mainly through fragmentation and nutrient sequestration (Siepel and Maaskamp, 1994). The voracious feeding activity of these mites on litter and other organic debris and decomposed plant parts result in their fragmentation and subsequent conversion in to heaps of nutrient rich faecal pellets.

During the food choice experiment, the mites were found grazing on the decomposed leafy and woody litter components of the mangrove plants, which were offered as test food items. The surfaces of such food substrates in advanced stages of decomposition were often found invaded by fungal colonies. Quite often, the fungal colonies were found to invade the remnants of food items provided in the culture cells also. Oribatid mites are known to perform active roles in decomposition of plant and fungal materials (Labandeira *et al.* 1997), by directly or indirectly interacting with decomposer

fauna, especially with the saprophytic fungi (Clement and Haq, 1984), which often serve as necessary precursors for initiation of the burrowing activity of the mites, by mechanically softening the plant tissues (Hayes, 1963). Microarthropods, including oribatid mites promote the microbial growth by feeding and disseminating fungal propagules by carrying these on their body setae and faecal pellets into new substrates. Comminution of organic residues by microarthropods especially the oribatids would increase surface area for microbial attack. When compared to macro arthropods like the millipedes and centipedes, the faecal pellets laid by oribatid mites have relatively greater surface to volume ratio than that of the original leaf litter which intensify the rate of decomposition per unit time (Coleman and Crossley, 2003). This would necessarily establish the role of these mites in nutrient cycling (Seastedt, 1984), thereby linking biodiversity and soil ecosystem function (Behan-Pelletier and Newton, 1999). Comparative analysis of micronutrients with oribatids and without oribatids carried out during the present study provided promising results by revealing significant increase in the concentration of nitrogen, phosphorous and potassium thereby shedding light on the positive impact of the feeding activity of these mites in mangrove soils also.

Oribatid mites, apart from their role in underground ecosystem, also would help in foliar litter decomposition, especially in canopy suspended soils (Lindo and Winchester, 2007). These mites mediate and enhance

decomposition of dead plant tissues by fragmentation, digestion and defecation (Macfadyen, 1964) and also help in germination of some fungi within their fecal pellets as the substrates (Shereef, 1971 and Luxton, 1972). In the case of intertidal oribatids, green algae serve as food of species living on intertidal rocks while the salt marsh species feed primarily on fungi (Schuster, 1979). Species of *Ameronothrus* were shown to browse on algal growths and around barnacles (Luxton, 1966), such marine inhabiting oribatids could be considered as opportunistic feeders (Norton *et al.* 1997).

Intertidal oribatid mites display diverse types of feeding habits. Some groups of the littoral oribatids browse on the living thalli of lichens, (Luxton, 1990), while some others are algivorous (Schuster and Schuster, 1977). Species of the family Ameronothroidea inhabit specifically on marine littoral zones where they feed upon marine microphytes, fungal hyphae on lichens or tidal debris in advanced stages of decomposition (Pugh 1988). The results of field sampling made during the present study enabled in the recovery of these mites from various food sources like the mangrove litter, pneumatophore, bark, algal cover growing on bark of mangrove plants, decomposing letter and so on, which was a clear indication on their diverse food sources also. Direct sampling of field collected littoral components enabled to visualize intensive feeding activity of various species of oribatid mites. The complete skeletonization of dead leaves of *A. marina* and *A. ilicifolius* with the exclusion of midrib and small veins was a common feature of some dominant

species of oribatids, as observed in the current study when they were reared in the culture cells, moistened with saline water. Such feeding behavior resulted in the production of large amount of faecal pellets on or around the feeding substratum. Similar feeding strategies were reported in terrestrial oribatid mite species (Haq, 1987, 2006, 2007; and Ramani and Haq, 2001) on rearing up on preferred food substances.

During the study, two species viz. *A. clavata* and *H. epimeratus* sp. nov. were selected for detailed observation on their embryonic development under laboratory conditions. The reproductive pattern of oribatids inhabiting mangrove ecosystems show variation depending on their environmental, physiological and morphological characteristics. The species *A. clavata* was found to complete its development from egg to adult within 61-72 days while the truly intertidal species, *H. epimeratus* sp. nov., completed its development from egg to adult within 82 – 102days. These two species were found associated with the mangrove litter, dead pneumatophores and from the algal cushions (*Microspora* sp.) growing on the barks and twigs of mangrove plants. This difference in duration of development could be attributed to the difference in the microhabitat and life style of the species.

The pattern of reproduction of *A. clavata* was found different from that of *H. epimeratus* sp. nov. The adult females of *A. clavata* disclosed the presence of developed pre-larvae inside their body cavity. Occurrence of a

pre-larval stage has been reported as a common feature in many oribatids (Webb, 1977; Clement and Haq, 1984; Schuster, 1988) and it is highly prevalent among phthiracaroid members. In the present study, females of *A. clavata* carrying mature prelarvae were found giving birth to fully developed larvae in the culture cells/among the feeding substrates and no oviposition was noticed. Such instances of prelarviposition and larviposition were already reported in terrestrial oribatids also (Norton 1994). Terrestrial oribatids often possess two types of larviposition in which larvae either emerge from the eggshell found inside the gravid females and are then deposited (true larviparity or viviparity), or larvae may hatch soon after deposition, the so called ovoviviparity (Haq *et al.* 1991a). Intertidal mites of the genus *Ameronothrus* inhabiting the marine littorals and estuaries show larviparity as an ancestral plesiotypic trait (Sovik 2003; Weigmann and Schulte, 1975; Pugh and King 1985; Bucking *et al.* 1998). Larviparity has several advantages over oviparity (Haq *et al.* 1991a; Norton 1994) and in intertidal mites which are constantly exposed to flood, occurrence of mixed parity and larviposition would help to overcome the washing effects of tidal currents (Sovik, 2003). The occurrence of tidal conditions for salt-marsh acarines shows viviparity stand a better chance for surviving to form a population (Luxton, 1964).

Detailed are lacking on the feeding and reproductive traits of marine/mangrove littoral inhabiting intertidal oribatids (Pfingstl, 2013). Intertidal

oribatids exhibit diverse patterns in spermatophore deposition and oviposition strategies under laboratory conditions. In the present study, the adult male of *H.epimeratus* sp.nov. were found to deposit stalked spermatophores singly on the walls and base of culture cells. The females of the species laid eggs inside the crevices, on algal cushions/ mass or in between the grains of sand on the substratum (floor of culture cells). Such spermatophore deposition and oviposition strategies were observed earlier in some intertidal oribatid species (Pfingstl, 2013c) viz. *A. inexpectatus*, *F. atlantica* and *C. bermudensis* which laid eggs in empty spaces and interstices of algal substrates. *A. inexpectatus* and *C. bermudensis* produced single, long (70-100µm) and fragile stalked spermatophores and medium sized (50-80 µm) group deposited spermatophores respectively. The presence of stalked spermatophores, as observed during the present study has been previously reported in truly intertidal oribatid mites inhabiting in marine and salt marshes (Thorell, 1871; Luxton, 1966; Sovik, 2004).

Results of laboratory studies showed that durations of the active and inactive stages including, egg- proto-deuto and tritonymph were in the range of 20 – 23, 10 – 13, 15 – 19 and 14 – 19 respectively for *H.epimeratus* gen.nov.sp.nov. Duration of egg stage of another intertidal species like *C. bermudensis* was shown to range from 17-22 days (Pfingstl, 2013b) and eggs of *F. atlantica* hatched after 15-16 days (Krisper and Schuster 2008). The eggs of *H. epimeratus* gen.nov.sp.nov., were found attached on algal cushions

and small crevices inside the culture cell. Such oviposition strategies in intertidal mites have already been under report (Pfingstl, 2013b and Luxton, 1990).

Dark brown coloured “Apherodermous” nymphal stages were found feeding on various stages of decomposed mangrove litter residues and completed quiescent and active phases within the culture chamber under laboratory conditions. The apherodermous juvenile instars of the Superfamily Ameronothroidea were recovered (Ermilov *et al.* 2012) from the moss samples under cliff near the seashores of Antarctic region. The earlier studies (Bayartogtokh *et al.* 2009; Pfingstl, 2012 a&b; 2013a, 2015a&b) enabled to record such apherodermous juveniles of Fortuyniidae and Selenoribatidae from various intertidal ecosystems including the littorals of mangrove and marine ecosystems. All the nymphal stages, were found to live inside the small cracks/crevices, on algal cushions. Adults and juveniles of the Ameronothroid genera also live in small lichens, especially in their “nests” in the crevices of the incrustated lichens, from where the deutonymph feed on the coccal algal cover (Schulte *et al.* 1975) and used as temporary refuge during inundation (Pugh, 1995). In most of the field collected truly intertidal mites, the integument of the juveniles was found composed of fine, granular cerotegument, which is very soft and plicate in nature except the centrodorsal plate. The juvenile instars of truly intertidal species of the genera like *Alismobates*, *Selenoribates*, *Carinozetes*, *Fortuynia* etc. possesses such

apophyses condition which are considered as adaptation to survive certain unpredictable tidal flooding, by serving as plastron structures, specifically helping in breathing under water (Pfingstl and Krisper, 2014). During flooding, inhabitants of the salt meadows crawl into cavities in the root system of plants on the surface of the soil (Schulte *et al.* 1975) and the presence of juvenile stages was observed only during periods of inundation (Behan-Pelletier & Eamer, 2003), thereby suggesting their inactivity in dry periods.

During the present study, the completion of studies on feeding and biological aspects of intertidal inhabiting oribatid mites was found as a difficult task because of some limitations in the laboratory conditions. The mangrove environment undergoes time-to-time changes by unpredictable periodic/ regular diurnal tidal rhythms, varied temperature, wind, salinity, and so it was found difficult to provide such specified natural climatic conditions in the laboratory for the successful establishment of the species. Further, the body size of species was very small, resembling the size of the members of the family Selenoribatidae that further hindered the progress of feeding and breeding experiments carried out in the laboratory (Schuster, 1979 and Pfingstl, 2013). Moreover, the feeding and breeding habits of the intertidal oribatids have to be synchronized with tidal rhythms (Schuster, 1979 and Luxton, 1990) which were not possible under laboratory conditions.

While summing up the results of the present study enabled to provide information on 23 species of oribatids belonging to 21 genera, 16 families and 10 superfamilies. Of these 6 were new to science. The study also enabled to record 20 species as new records from mangrove ecosystems of North Kerala. The new species erected were *H. aureus* sp.nov.(Lohmanniidae), *S.mangrovius* sp.nov.(Selenoribatidae), *Holocarinozetes* gen.nov., *H. epimeratus* gen.nov.sp.nov. sp.nov.(Fortuyniidae), *P.kadalundiensis* sp.nov. (Oribatulidae), *P.(P.) trifolius* sp.nov. and *T. (R.) nortoni* sp.nov. (Haplozetidae). The study further revealed that these mites could successfully get adapted to thrive in the challenging ecosystems by possessing some morphological modifications which are considered as important factors determining the distribution of oribatid species along different mangrove littoral zones. An in depth study on the physiology, ecology and feeding biology of individual intertidal oribatids is highly essential and need of the hour for the confirmation/ elucidation of their active role in extremely productive ecosystems like the mangroves.

CHAPTER 13

SUMMARY

Despite the significant roles played by oribatid mites in various ecosystem processes like organic decomposition, nutrient cycling leading to enrichment of soil productivity, bioindication, biological control etc. relatively very little attention has been received by this group in Indian scenario. Our country, with its motto of intensifying agricultural production and biodiversity conservation should encourage studies on the inventorying of alpha diversity of faunal groups and elucidation of their impact in the bioremediation and ecosystem restoration, as a part of stabilizing economic status of the nation. Being a country among the top megadiversity nations of the world and which relies mainly on agricultural production to support the livelihood of its people, the role of oribatid mites should be elucidated properly in India for their subsequent utilization in organic farming practices, as a substitute for artificial fertilizers. Species diversity and numerical abundance of oribatid mites generally exceeds that of the other microarthropods in most of the terrestrial ecosystems, especially in forest soils and litter accumulated areas. Mangroves, being the most productive ecosystems of the tropical and subtropical countries and which form the transitional zones of marine and freshwater ecosystems have received much attention from the scientific and public sectors of the world. These intertidal

regions provide good shelter, breeding and feeding habits for both terrestrial and aquatic vertebrates and invertebrates and the vegetation of which offer large amounts of litter, which would serve as the major source of organic matter for the survival and replenishment of extremely diverse faunal entities. However, the rich diversity of mangrove fauna is yet to be studied in detail in order to understand the functional impact of individual group on this productive ecosystem.

Our present knowledge on the species composition and diversity of oribatid mites is still a very poorly explored area on a global level and is apparently null as far as India is concerned. The ecological role of any individual taxon can be better understood only after gaining knowledge on its accurate species identity. A better understanding of the feeding habits is highly essential for assessing the role of oribatid mites in the degradation process and subsequent enrichment of the fertility status of mangrove soils. Giving due recognition to the above and to fill up this lacuna to the possible extend, the present research work was undertaken with an intention to explore the diversity and species composition of oribatid mites inhabiting the mangrove ecosystems of North Kerala and also to gather information on the feeding habits and developmental parameters of selected common species of local importance. It was also thought to elicit knowledge on the feeding impact of these mites in mangrove soils through quantitative analysis of the

nutrient levels, especially the levels of N, P, K in mangrove soils with and without oribatid mites.

The present thesis is divided into three parts for the inclusion of the types of work carried out on the mangrove dwelling oribatid mites. The first part of the thesis deals with the details of the general surveys carried out for the recovery of oribatid mites from the various mangrove ecosystems of North Kerala, including the descriptions of the vegetational and other topographic characteristics of the various sites and data on the distribution pattern of the various species in the sites screened, species composition of the various sites etc. Collection of oribatid mites was carried out by conducting random sampling of mangrove soils, litter and other organic debris etc. from the various sites of 15 mangrove ecosystems distributed over 4 districts viz. Malappuram, Kozhikode, Kannur and Kasaragod to recover the associated oribatid fauna. Data on the vegetational and climatic parameters of the sampling sites were well documented and the samples containing mangrove soils, litter, pneumatophores, leaves, decomposing twigs/bark etc., were collected from these ecosystems and subjected to extraction under the Open-brass funnel apparatus and through direct microscopic examination under a stereozoom microscope in the laboratory. The washing method (Karasawa *et al.* 2005) was also employed with slight modification for the collection of arboreal or canopy dwelling oribatid mites. The oribatid specimens thus recovered were either preserved in 70% alcohol for subsequent taxonomic

studies or collected alive for further rearing and conduct of feeding/breeding studies. The preserved specimens were processed through alcohol grades, cleared in clearing medium (lactic acid and absolute alcohol mixed in 1:1 ratio) and the temporary and permanent slide mounts were made in glycerin or Hoyer's medium respectively for taxonomic studies.

The second part of the thesis comprises the taxonomic descriptions of the various species recovered from the collection sites. Identification of the species was done under a Carl Zeiss Research Microscope, following the identification keys of Balogh and Balogh (1992 and 2002), Walter (2011). Additionally, relevant literature on various taxa were also referred for identification and help from experts was also sought for confirmation of identity of doubtful species. Systematic position and classification of the recovered species of mites were decided following the most recent World Oribatid mite Catalogue compiled by Subias, 2004 (updated in 2015). Detailed morphological features of individual species were drawn using a prism type Camera Lucida attached to a Unitron research microscope. Measurements of the specimens were made using an ocular micrometer. Relevant photographs of the structures/areas of taxonomic importance of the various species were made using Carl Zeiss research microscope (**AXIOSKOPE-2 PLUS, ZEISS, GERMANY**). In addition, SEM images of selected mangrove dwelling oribatid species were taken at the National

Institute of Technology (**NIT**), Calicut using Hitachi SU6600 Variable Pressure Field Emission Scanning Electron Microscope (FESEM).

In the taxonomic part of the thesis, detailed descriptions and illustrations of 23 species were included. The above 23 species were found to belong to 21 genera, 16 families and 10 Superfamilies. Results of taxonomic analysis showed that out of the 23 species, 6 species representing 6 genera, 6 families and 3 superfamilies were new to science. The new taxa identified were *H. aureus* sp.nov.(Lohmanniidae), *S. mangrovius* sp.nov., (Selenoribatidae), *Holocarinozetes* gen.nov., *H. epimeratus* sp.nov., (Fortuyniidae), *P. kadalundiensis* sp.nov., (Oribatulidae), *P.(P.) trifolius* sp.nov. and *T. (R.) nortoni* sp.nov., (Haplozetidae). The species viz. *A. unilateralis* Hammer, 1973; *H. hirsutus* Wallwork, 1964; *J. (J.) porosus* Hammer, 1979; *A. clavata* Markel, 1964; *H. (H.) vitrina* (Berlese, 1913) ; *A. arboreus* Ramani & Haq 1992; *A. longisetosus* Aoki 1965; *C. (K.) penicillus* Mahunka, 1979; *L. (P.) bengalensis* Bhaduri and Raychaudhuri 1968; *S.(S.) malabarica* Ramani & Haq, 1998; *P. (Protoribates) capucinus* Berlese, 1908; *I.(I.) punctulatus* (Sellnick, 1925) and *G.(G.) paragibbula* Weigmann, 2011 were recorded for the first time from the mangrove ecosystems of Kerala. Members of truly intertidal oribatid families like Fortuyniidae and Selenoribatidae could be recorded for the first time from the mangrove ecosystems of the oriental region, especially from the Indian subcontinent.

Data on the systematic position and distribution were tabulated and presented.

In the third part of the thesis, data on the feeding and breeding habits as well as morphological adaptations of selected species of mangrove dwelling oribatids were presented. Data on the general feeding habits of field-collected specimens also were recorded and presented. During field sampling, several species of oribatid mites were found associated with true mangrove plants as well as mangrove associates from the various sites screened. The euphthiracarid mite, *A. clavata* revealed a close association with the filamentous green alga, *Microspora* sp. on which the various life stages of the mite exhibited voracious feeding trend. Both fresh and decayed filaments of the alga were found nibbled by the mite and subsequently exhibited tunneling activity on the bark. All the life stages viz. egg, larva, three nymphal stages (proto-, deuto- and tritonymph) and their respective quiescent phases also could be recovered from the algal filaments. Intensive feeding of the adults and nymphs resulted in the production of large number of brown and green coloured faecal pellets in the culture cells. The gut contents of the nymphal stages with green coloured algal globules confirmed algal diet as the preferred food item.

Certain oribatid species were found associated with dead/ decaying parts of true and associate mangrove plants. *A. clavata* showed association

with the dead pneumatophores of *A. marina*, *P. kadalundiensis* sp.nov., with dead leaves of *A. officinalis*, *P.(P.) trifoliatum* sp.nov., with dead bark of *D. trifoliata* and *I. (I.) punctulatus* with decaying twigs of *C. crista*. Active feeding by these mites was observed in the laboratory which resulted in the formation of feeding tunnels and channels inside the twigs, which were found, packed with faecal pellets. Studies on the microhabitat preference of selected species revealed their specificity to rely on different vegetations including the spikelets of mangrove associate grass plants like *M. javanicus*. The latter was found to grow up to 2 meters in height from the ground level and which was selected as the most preferred food item by the species, *S.(S.) malabarica*. The dead and decomposing spikelets of the grass were recognized as the most preferred microhabitat for the replenishment of the species.

Feeding habits of two species viz. *A. clavata* (Märkel, 1964) and *I. (I.) punctulatus* (Sellnick, 1925) were studied under laboratory conditions. Cafeteria experiment (Hubert, 2003) with slight modification was used for conducting the food choice/preference test. In this experiment, the euphthiracarid mite, *A. clavata* was provided with varied natural food items collected from the mangrove ecosystems under laboratory conditions. The species was cultured in plastic culture cells based with a mixture of plaster of Paris-charcoal (4:1 ratio) for 5 successive days on test food items like leaf litter, barks of *A. marina* covered with the algal growth of *Microspora* sp., moistened leaves of *A. ilicifolius* and *A. marina* and dried and remoistened

pneumatophores of *A. marina* were offered . Results of the cafeteria experiment revealed that the adults and juvenile stages of *A. clavata* preferred to feed on the cortex (gas- filled aerenchyma cells) and pith regions of the pneumatophores and totally excluded the epidermis and pericycle of the same. The oribatid species viz. *I.(I) punctulatus* and *P.(P.)trifoliatus* were found actively feeding up on the decomposing woody parts of the mangrove associate plants like *C. crista* and *D.trifoliata*.

The impact of feeding activity of oribatid mites in the soil ecosystem leading to the enhancement of fertility and productivity of the mangrove ecosystem was made through comparative analysis of micronutrients (N, P, K) in mangrove soils. Quantitative analysis of the micronutrients present in the experimental and control soil samples was carried out at Centre for Water Resource Development and Management (CWRDM) Calicut. The data obtained on quantitative analysis of micronutrients up on statistical analysis following unpaired student 't' test for N,P,K were proved significant at, $4.384 \pm 0.496\text{ppm}$, $25 \pm 2.78\text{ppm}$ and $11.218 \pm 0.606\text{ppm}$ respectively, confirming that oribatid mites play substantial role in enhancing the nutrient levels of the mangrove soils

In the present study, developmental studies of 2 selected species viz. *A.clavata* and *Holocarinozetes epimeratus* sp.nov., were also performed under laboratory conditions, on their preferred food items, collected from respective

natural habitats. The postembryonic development was traced in plastic culture cells based with plaster of Paris-charcoal mixture (4:1 ratio) at room temperature of $28 \pm 2^\circ\text{C}$ and Relative Humidity (RH) of $79 \pm 2\%$. The gravid females of *A.clavata* showed the presence of varying numbers of eggs carrying mature pre- larvae inside their body cavity, in which well developed claws and setae were clearly visible. The duration of life stages of *A.clavata* from egg to adult could be recorded as 61-72 days at $(28 \pm 2^\circ\text{C})$ and RH $79 \pm 2\%$ and salinity of 7.9 ± 2 . (pH of saline water collected from natural habitat which was used for rearing). The juveniles of this species were found aggregating on the drops of saline water adhered to the walls of the culture cells .

The duration of development of *H. epimeratus* sp.nov., from the egg to adult stage could be recorded as 82-102 days under the same conditions of temperature, RH and salinity. In the laboratory, most of the larvae were found occupying inside the feeding channels formed by the feeding activity of the species. Confinement of the immature stages to cryptic habitats like the inner sides of feeding tunnels might be an adaptation to ensure protection to developing stages from unpredictable environmental conditions like the frequent tidal floods. The association of these mites with the dead plant materials coupled with the possession of morphological adaptations and altered reproductive traits like ovoviviparity and larviposition would serve to reduce the risk of eggs and other life stages from getting washed away by the

tidal currents. This was further confirmed through the results of field cum laboratory observations on the possession of monodactylous legs with longer, hooked, sickle shaped claws bearing prominent proximoventral tooth in littoral species (eg. *S. mangrovius* sp.nov., and *H. epimeratus* sp.nov.). In contrast to the tridactylous legs with short claws seen in soil/ litter and canopy dwelling (arboreal) species. Modifications in the claw morphology might be interpreted as an adaptation to give firm grip on plants/litter ingredients during unpredictable environmental changes like wind and rain for arboreal oribatids and tidal flooding for littoral forms. Such morphological cum reproductive adaptational features observed in mangrove dwelling/littoral species of oribatid mites would ensure protection for their survival in highly challenging environments like the mangrove ecosystems which are constantly exposed to frequent and unpredictable tidal floods.

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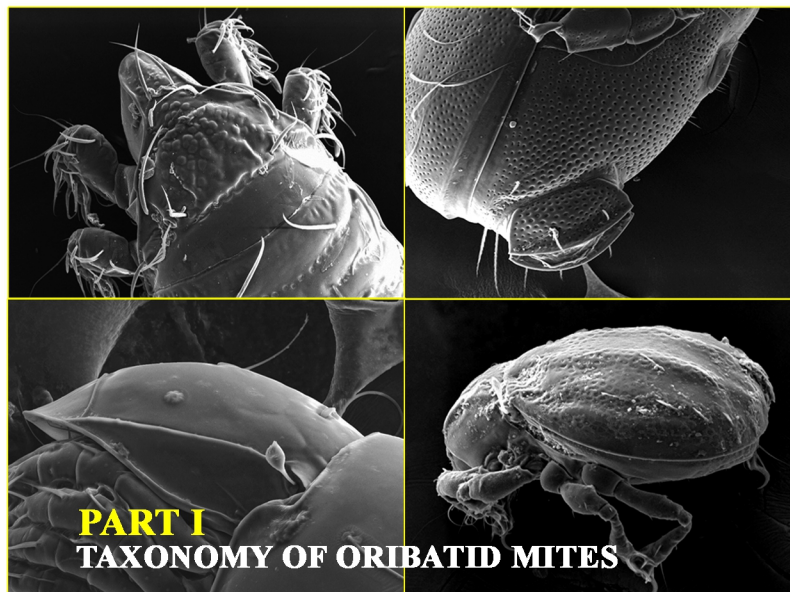
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Chapter 1	- Introduction
Chapter 2	- Review of Literature
Chapter 3	- Materials and Methods
Chapter 4	- General External Morphology and Terminology of Oribatid Mites
Chapter 5	- Observation
Chapter 6	- Systematic Position of the Species Described
Chapter 7	- Description of Species



Chapter 8 - Introduction

Chapter 9 - Review of Literature

Chapter 10 - Materials and Methods

Chapter 11 - Observation

PLATE 1

Global distribution of oribatid mites according to Subias,2004 (updated in 2015)

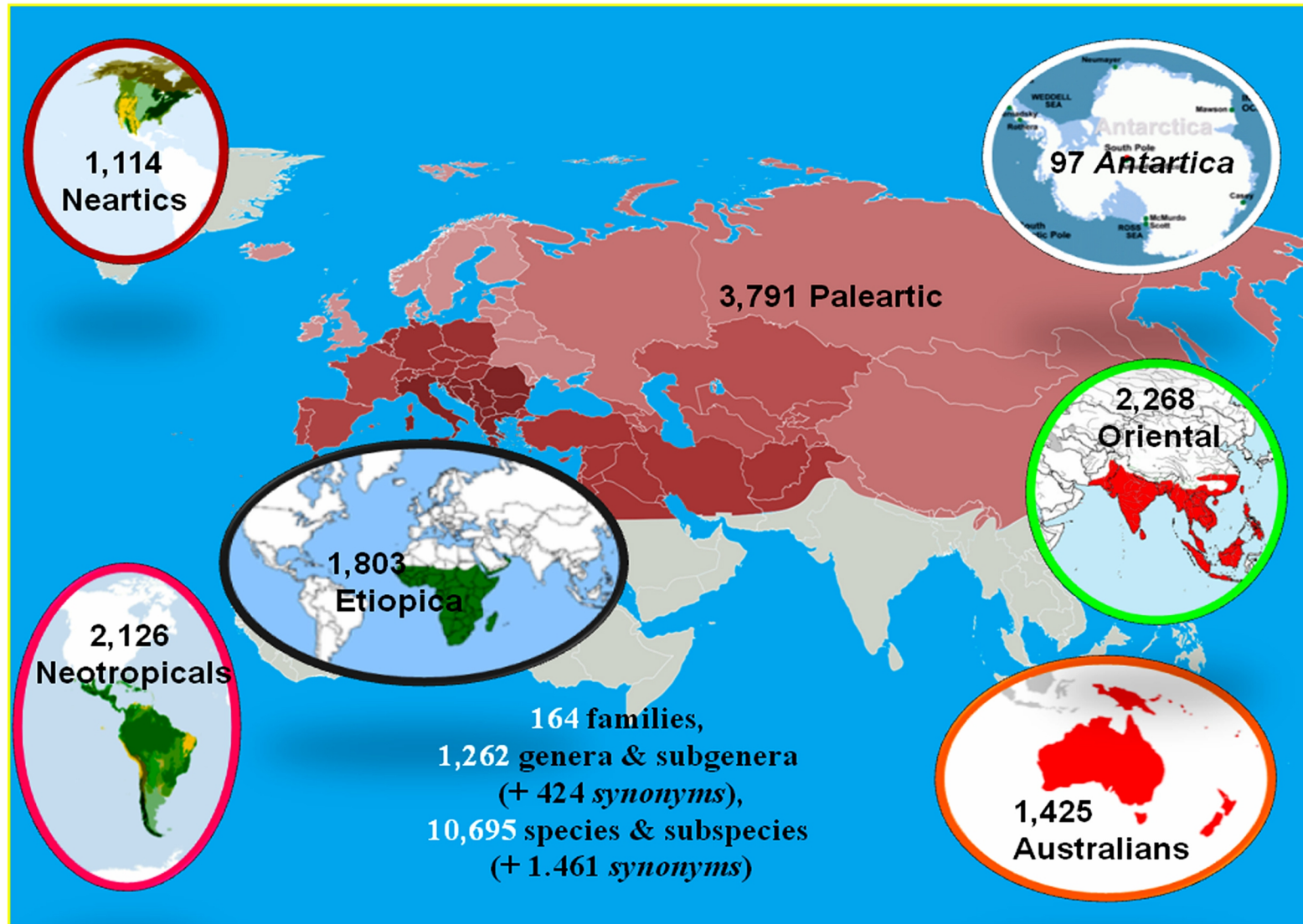


PLATE 2

Mangrove Sampling Sites

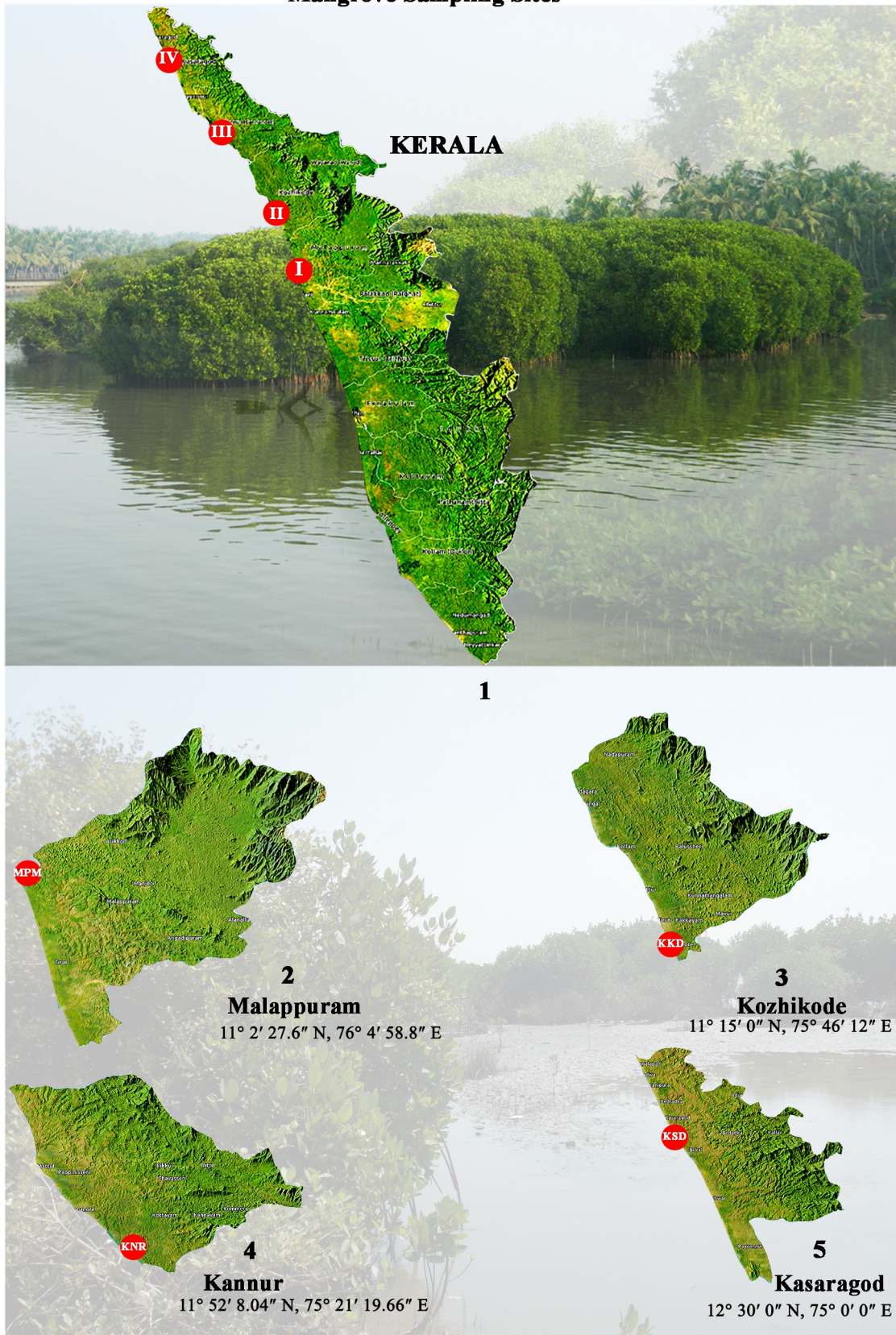


Fig.1. Map of Kerala showing mangrove sampling sites at 4 districts; **2.** Malappuram (MPM); **3.**Kozhikode(KKD); **4.**Kannur(KNR); **5.**Kasaragod(KSD).

PLATE 3

Major Mangrove Vegetation of the Area Surveyed



Fig.1. *Acanthus ilicifolius* L.; **2.** *Aegiceras corniculatum* (L.) Blanco; **3.** *Avicennia marina* (Forsk.) Vierh.; **4.** *A. officinalis* L. **5.** *Bruguiera cylindrica* (L.); **6.** *Excoecaria agallocha* L.; **7.** *Rhizophora apiculata* Blume.; **8.** *R. mucronata* Blume.

PLATE 4

Major Mangrove Vegetation of the Area Surveyed

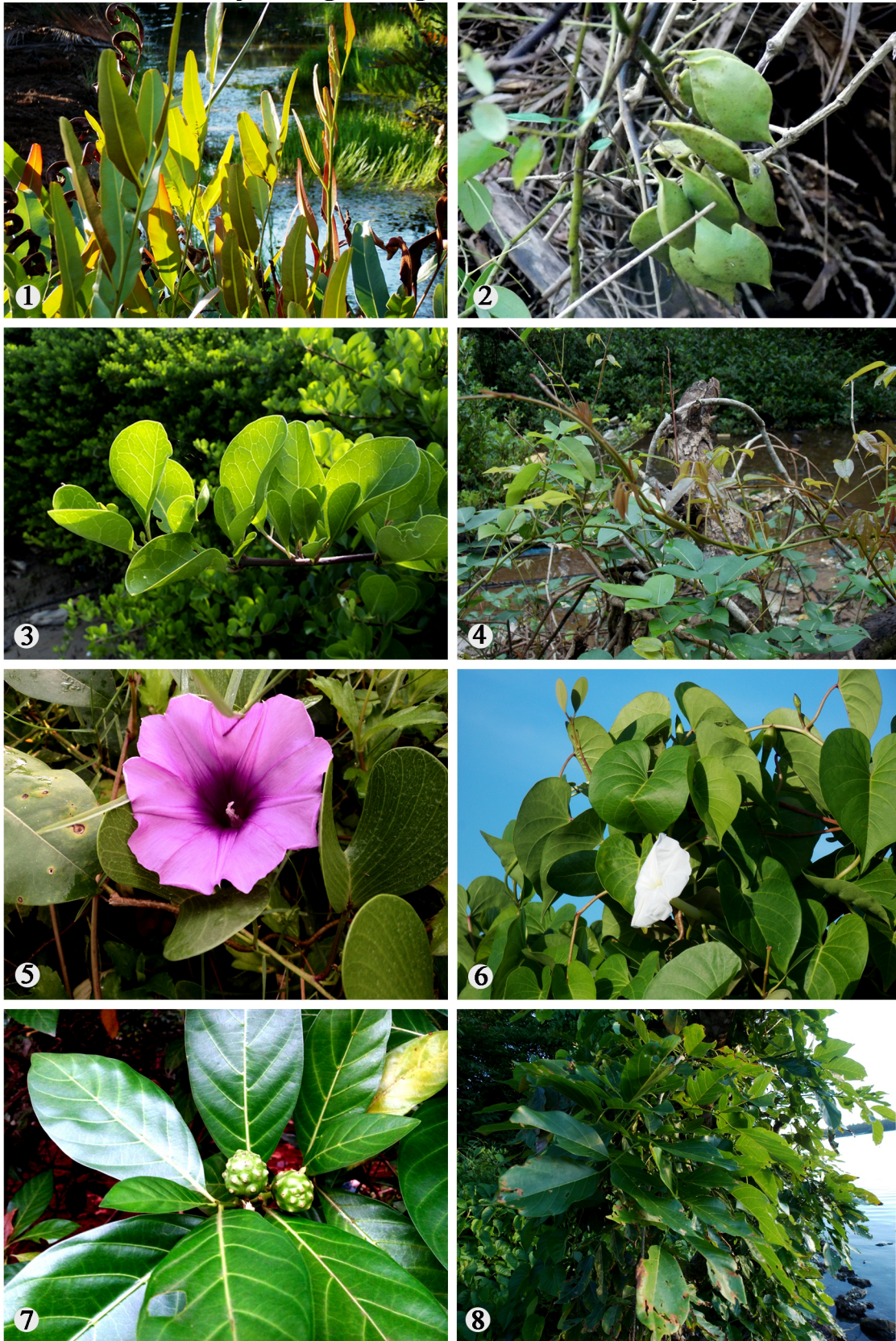


Fig.1. *Acrostichum areum* L.; **2.** *Caesalpinia crista* L.; **3.** *Clerodendrum inerme* (L) Gaertn.; **4.** *Derris trifoliata* Lour.; **5.** *Ipomoea pes-caprae* (L) R.Br.; **6.** *Ipomoea violaceae* L.; **7.** *Morinda citrifolia* L.; **8.** *Pongamia pinnata* (L) Pierre.

PLATE 5

Major Mangrove Vegetation of the Area Surveyed

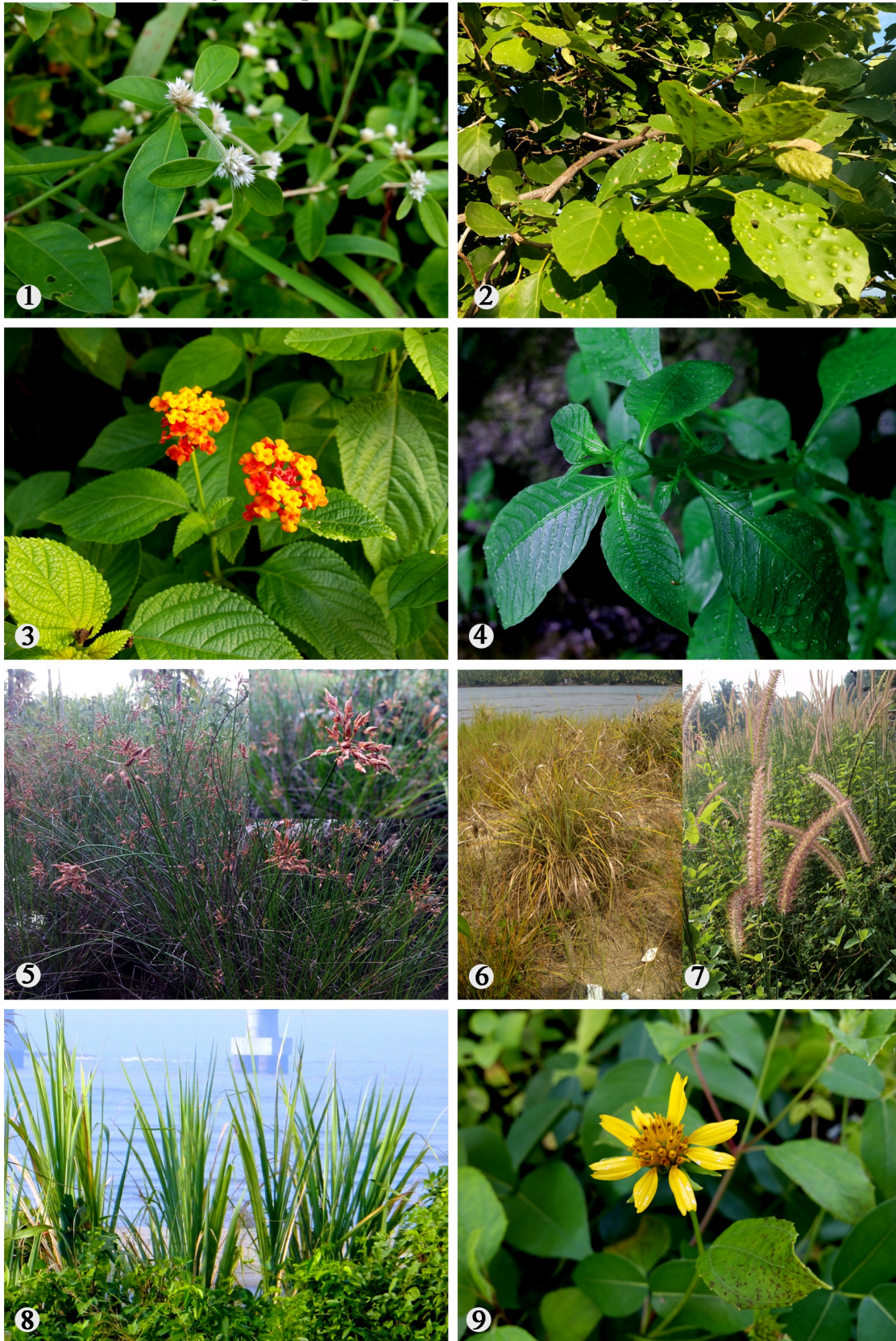


Fig.1. *Alternanthera bettzickiana* (Rogell); **2.** *Premna serratifolia* L.; **3.** *Lantana camara* L.; **4.** *Ludwigia hyssopifolia* (G.Don) Exell.; **5.** *Fimbristylis ferruginea* (L.) Vahl.; **6.** *Mariscus javanicus* (Houtt.) Merr & Metcalf.; **7.** *Pennisetum pedicellatum* Trin.; **8.** *Saccharum arundinaceum* Retz.; **9.** *Wedelia chinensis* (Osbeck) Merr.

PLATE 6

Sampling Localities



Fig.1. Brahmasampadam (BRSPM); **2.** Olipramkadavu (OPKDV); **3.** Kadalundi-Vallikkunnu community reserve mangrove –I (KVCR-I); **4.** Kadalundi-Vallikkunnu community reserve mangrove –II (KVCR-II); **5.** Kottakkadavu (KTKDV); **6.** Kallai (KLAI); **7.** Mankavu (MNKV). **7a.** Inside the mangrove vegetations.

PLATE 7

Sampling Localities



Fig 1. Thalassery (TLSRY); 2. Koduvalli (KDVLY); 3. Valapattanam River bank (VLMRVR) 4. Dharmadam (DRMDM) ;5. Ezhome (EZHM-I); 6. Ezhome (EZHM-II); 7. Pazhayangadi (PNGDY); 8. Nileswaram (NLSRM).

PLATE 8

Mangrove Samples



Fig.1. Mangrove soil; **2.** Mangrove litter ; **3.** Mangrove Pneumatophores of *A. marina* ; **4.** Flooded trunks of *A. marina*; **5.** Alga attached on mangrove plant *A. marina* ; **6.** Tidal debris left after high tide (arrow) ; **7.** Dead mangrove associate grass, *M. javanicus*; **8.** Twigs of *A. marina* with attachment of green alga, *Microspora* sp.(Arrow)

PLATE 9

Materials and Methods: Oribatid Mite Extraction

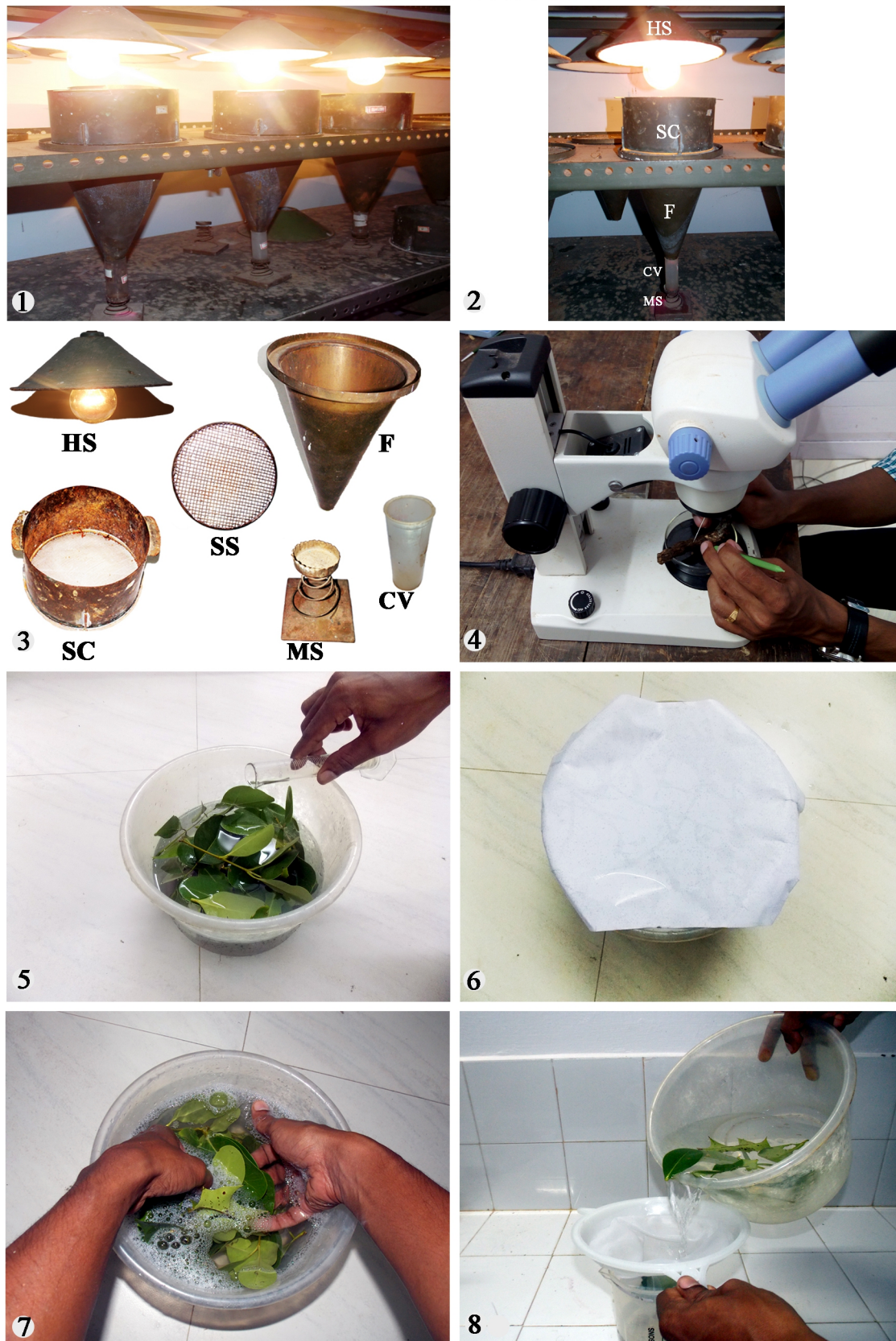
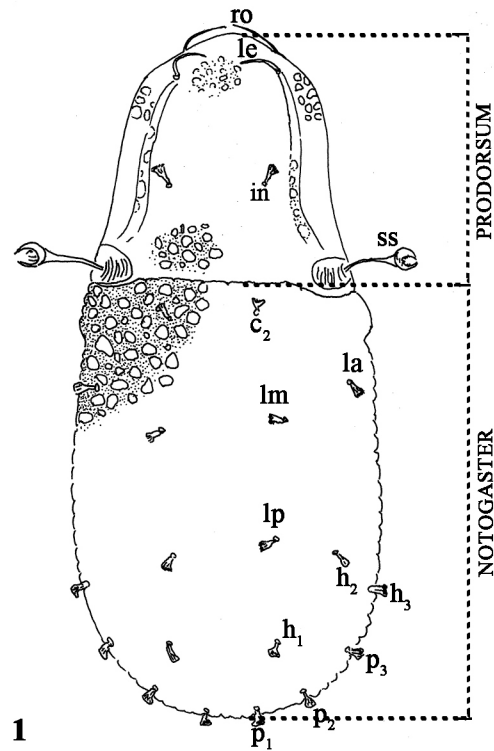


Fig.1.Open brass funnel Apparatus; **2.** A View of a single Unit showing the Heat Source(HS), Sample Container(SC), Funnel (F), Collection Vial (CV) and Metal Spring with Base (MS); **3 -** A Closer View of the Separated Components of A Single Extraction Unit showing - Heat Source (HS), Sample Container (SC), Supporting Shield (SS), Funnel (F), Collection Vial (CV) and Metal Spring with Base (MS); **4.** Direct Sampling under Stereozoom Microscope; **5-8.** Different steps in Washing Method.

PLATE 10

General External Morphology and Terminology of Oribatid Mites



100µm

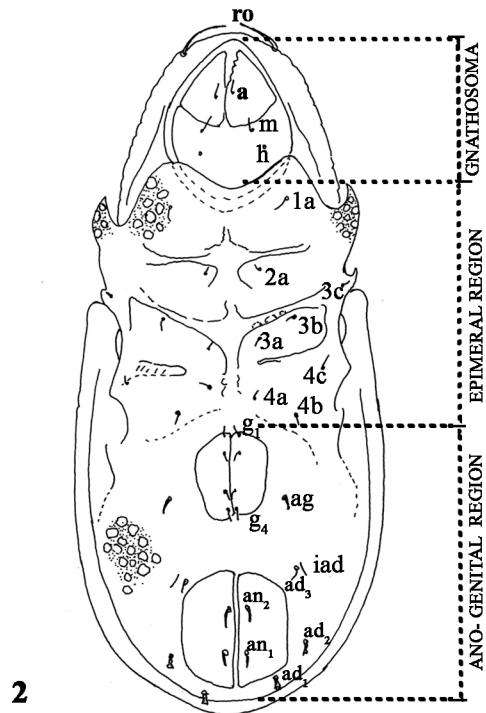


Fig. 1.Dorsal Region ; 2.Ventral Region.

PLATE 11

Different Types of Setae

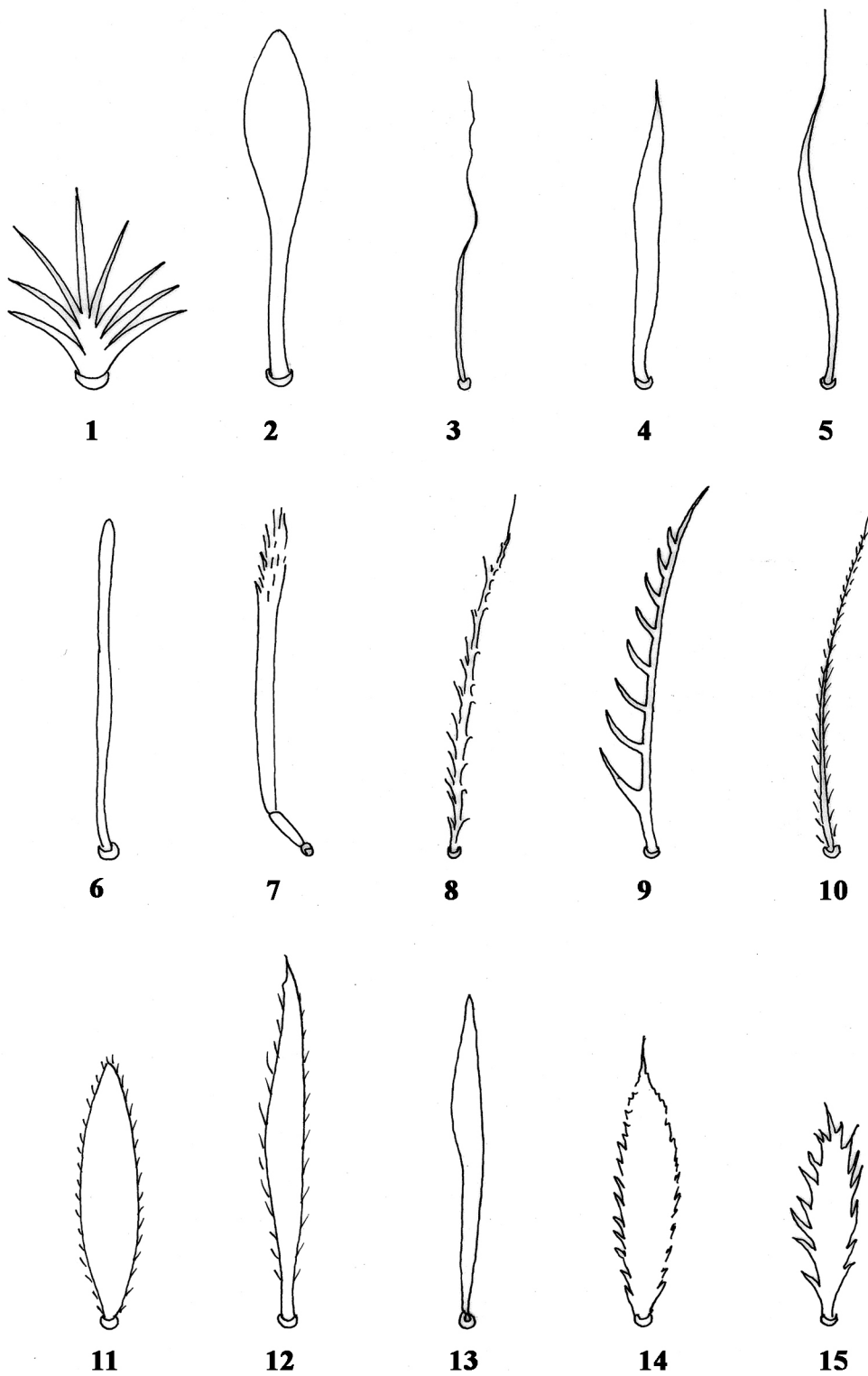


Fig. 1. Arboriform; 2. Clavate; 3. Flagelliform; 4. Foliolate; 5. Setiform; 6. Spiniform; 7. Brocate; 8. Ciliate; 9. Pectinate; 10. Pennate; 11. Barbed; 12. Ciliate; 13. Entire; 14. Serrate; 15. Spinose.

PLATE 12

Different Types of Setae

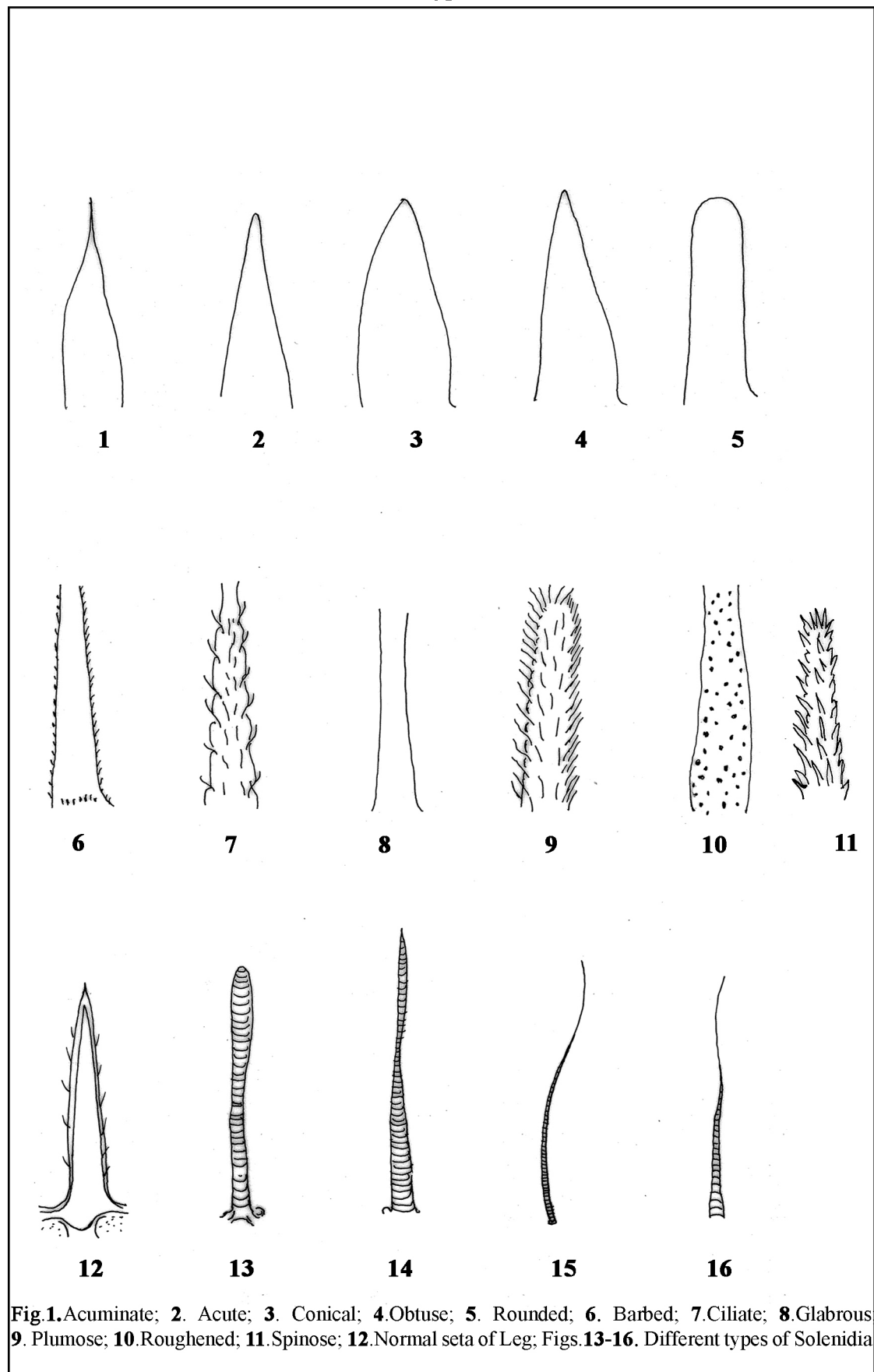
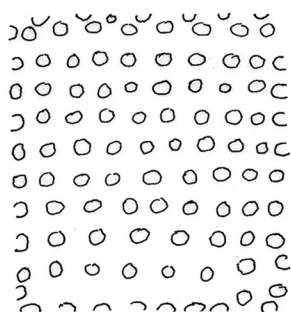
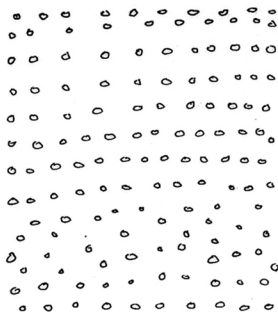


PLATE 13

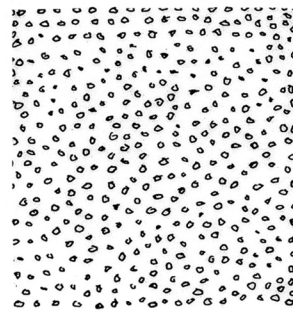
Different Types of Notogastral Ornamentations in Oribatids



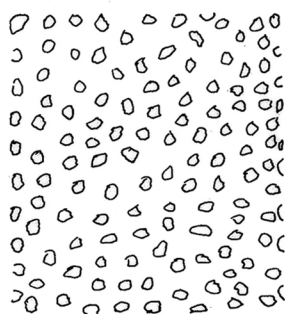
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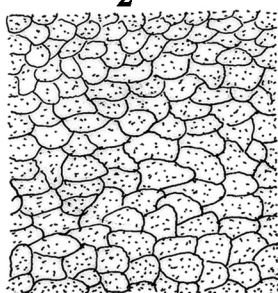
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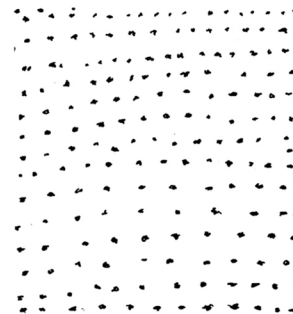
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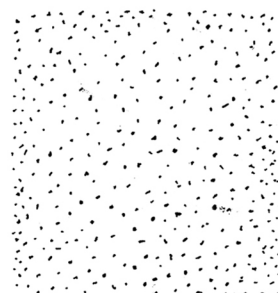
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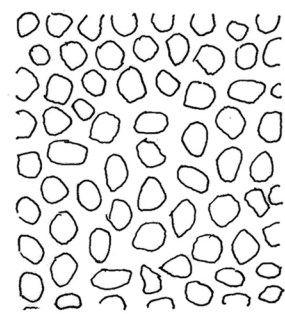
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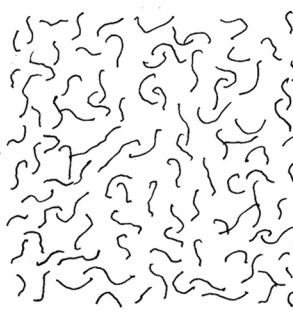
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8



9



10

Fig.1. Alveolate; **2.** Foveolate; **3.** Granulate; **4.** Maculate; **5.** Polygonate; **6.** Punctate; **7.** Punctulate; **8.** Reticulate; **9.** Rugose; **10.** Rugulose.

PLATE 14

Diversity of the Mangrove Dwelling Oribatid Mites in the Study Sites

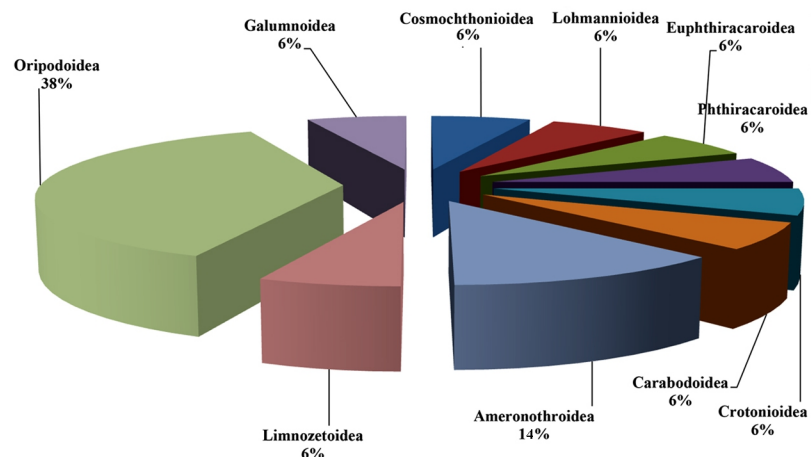


Fig.1. Family Diversity of the Mangrove Dwelling Oribatid Superfamilies in the Study Sites

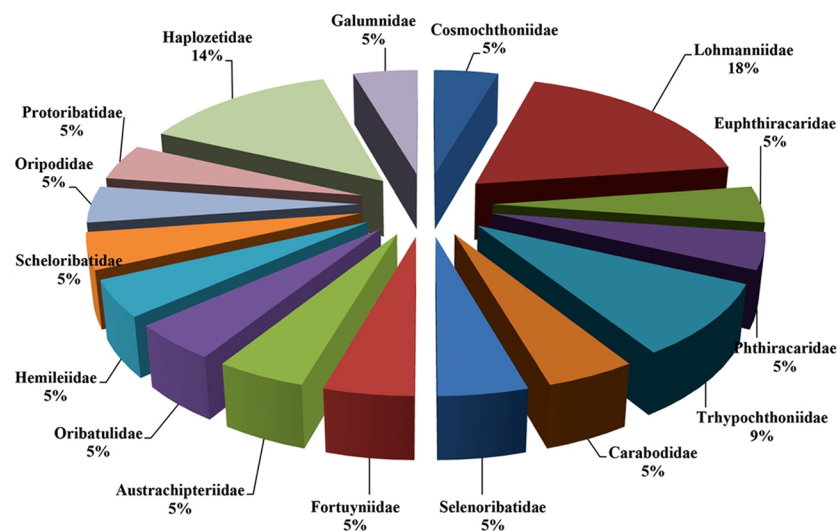


Fig.3. Generic Diversity of the Mangrove Dwelling Oribatid in the Study Sites

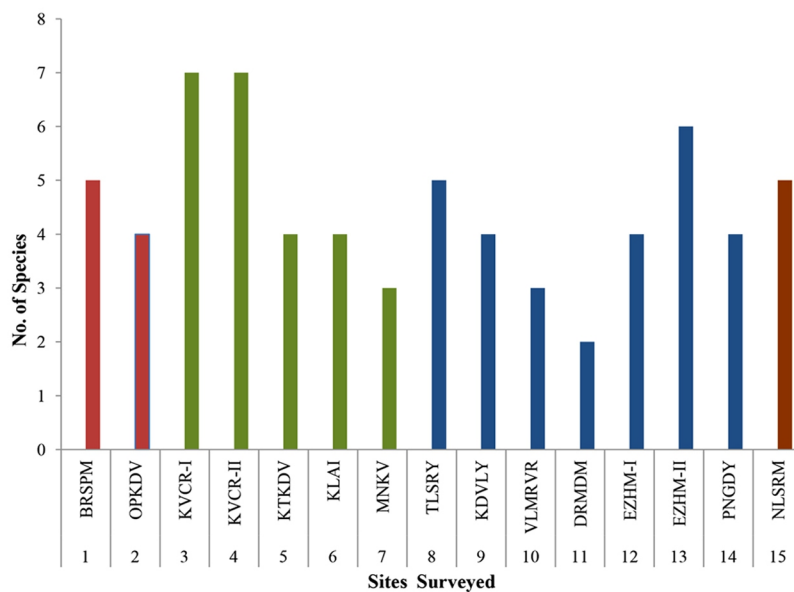


Fig.4. Species Diversity of the Mangrove Dwelling Oribatids in the Study Sites

PLATE 15

Cosmochthonius (Cosmochthonius) reticulatus Grandjean, 1947

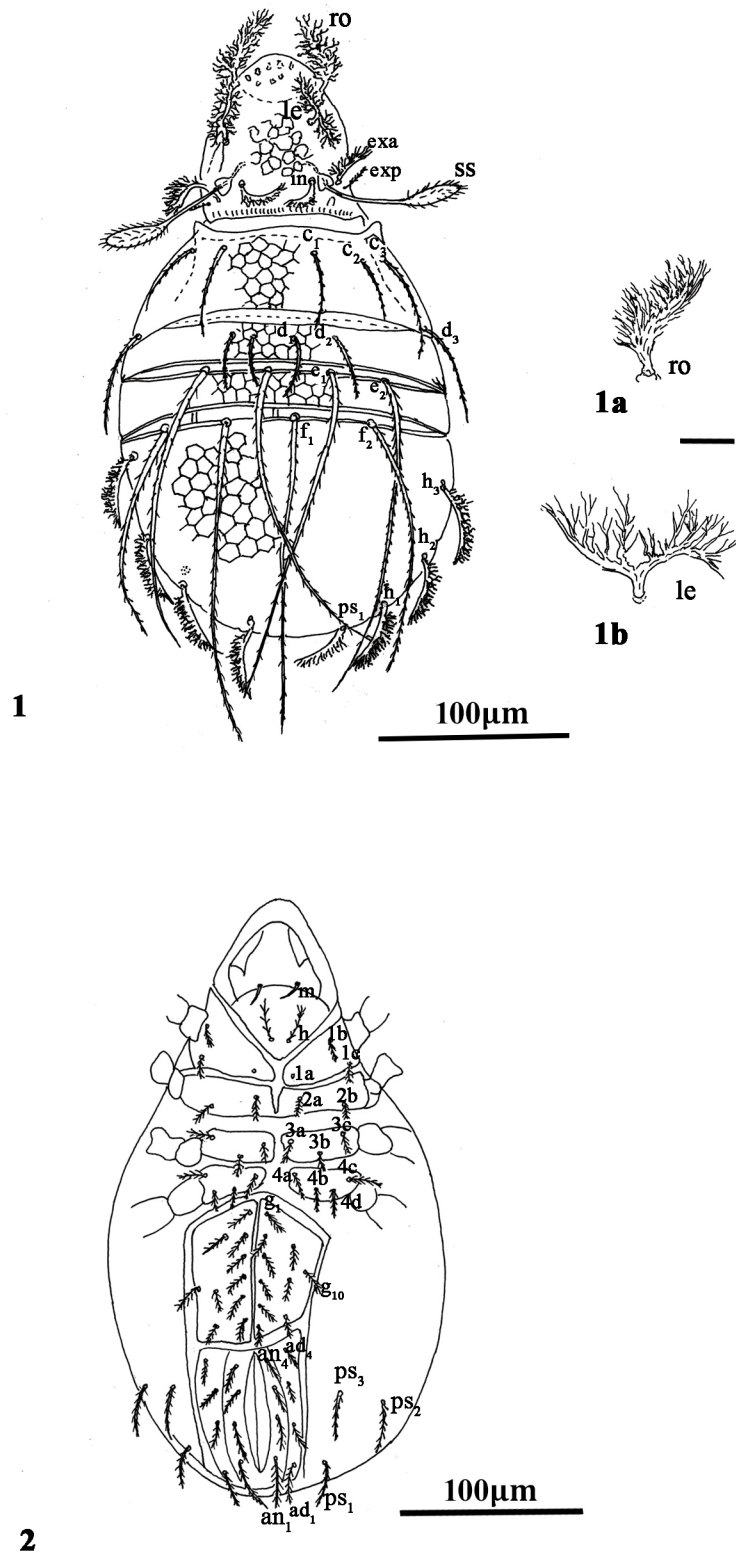


Fig. 1. Dorsal View; 1a. Rostral seta (ro); 1b. Lamellar seta (le); 2. Ventral View.

PLATE 16

Annectacarus unilateralis Hammer, 1973

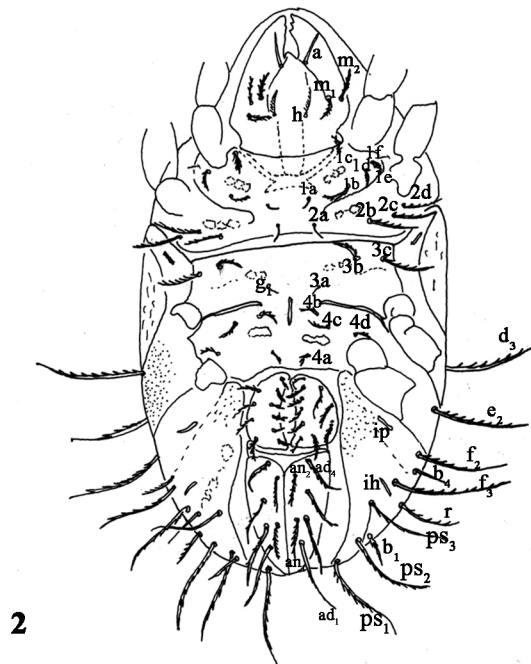
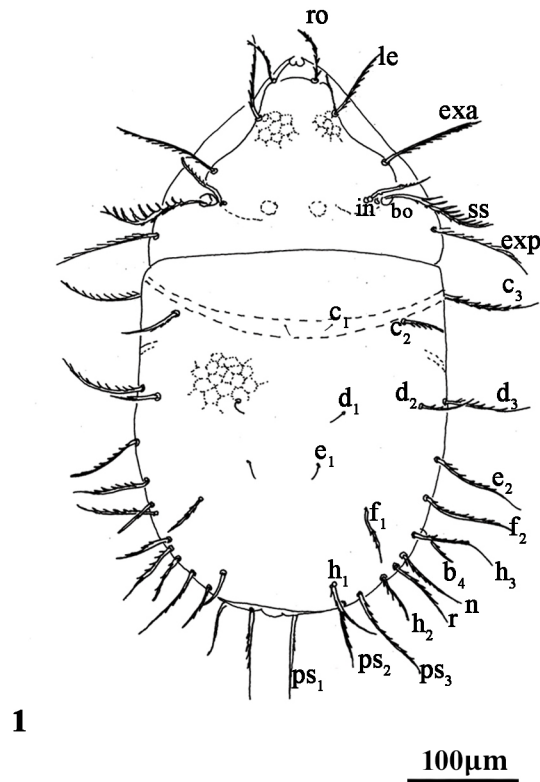
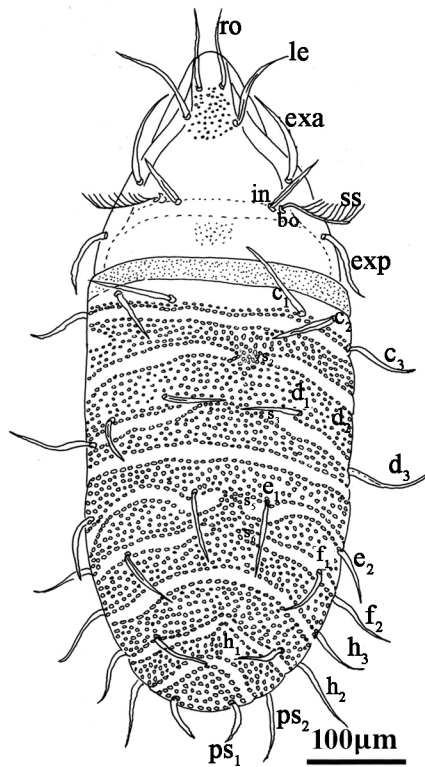


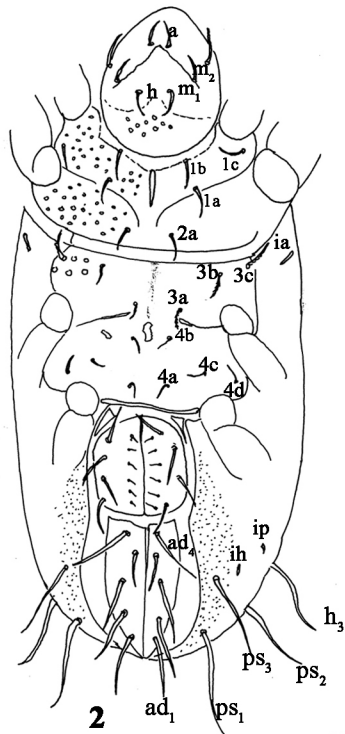
Fig. 1. Dorsal View; 2. Ventral View.

PLATE 17

Haplacarus aureus sp.nov.

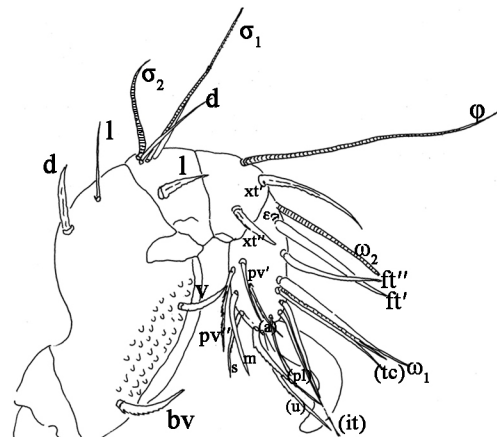


1



2

100μm



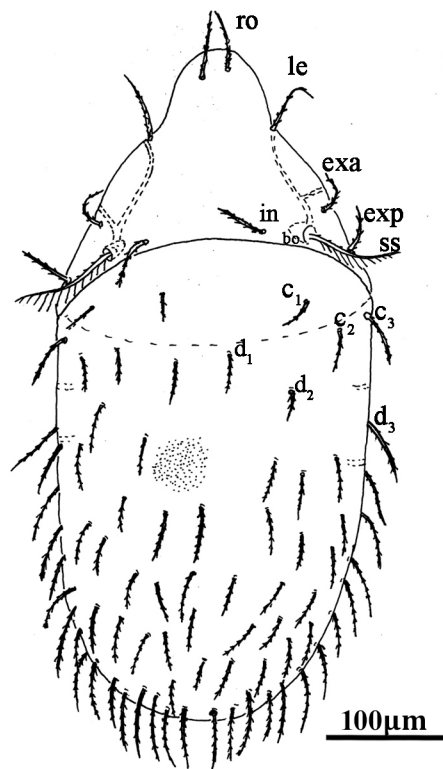
100μm

3

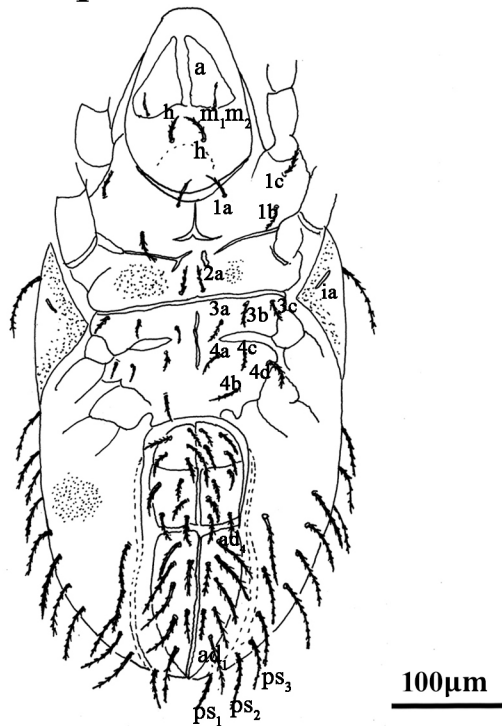
Fig. 1. Dorsal View; 2. Ventral View; 3. Leg I.

PLATE 18

Heptacarus hirsutus Wallwork, 1964



1



2

Fig. 1. Dorsal View; 2. Ventral View.

PLATE 19

Javacarus(Javacarus) porosus Hammer, 1979

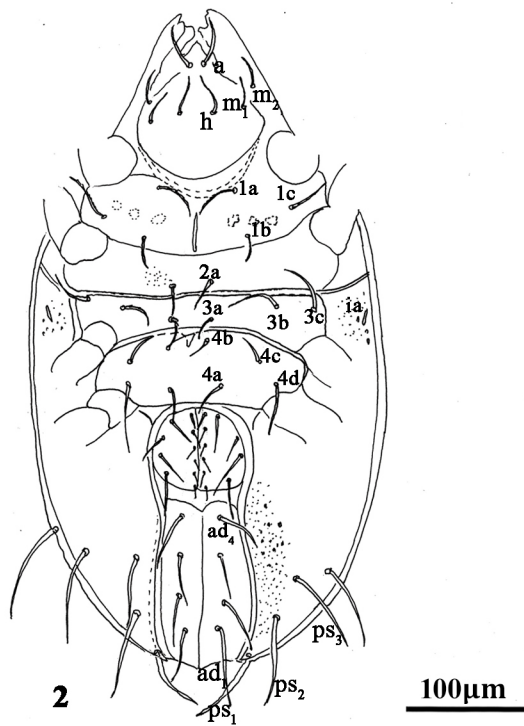
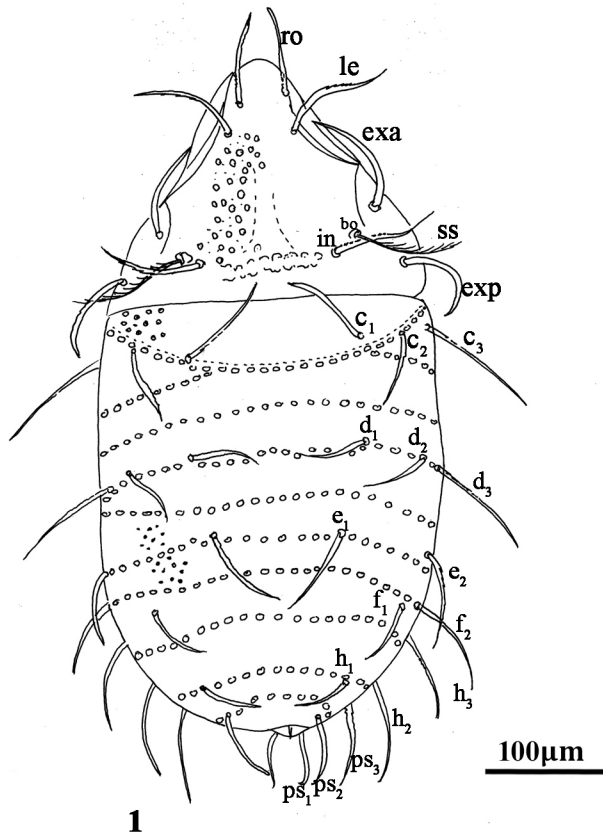


Fig. 1.Dorsal View; 2.Ventral View.

PLATE 20

Javacarus(Javacarus)porosus Hammer, 1979

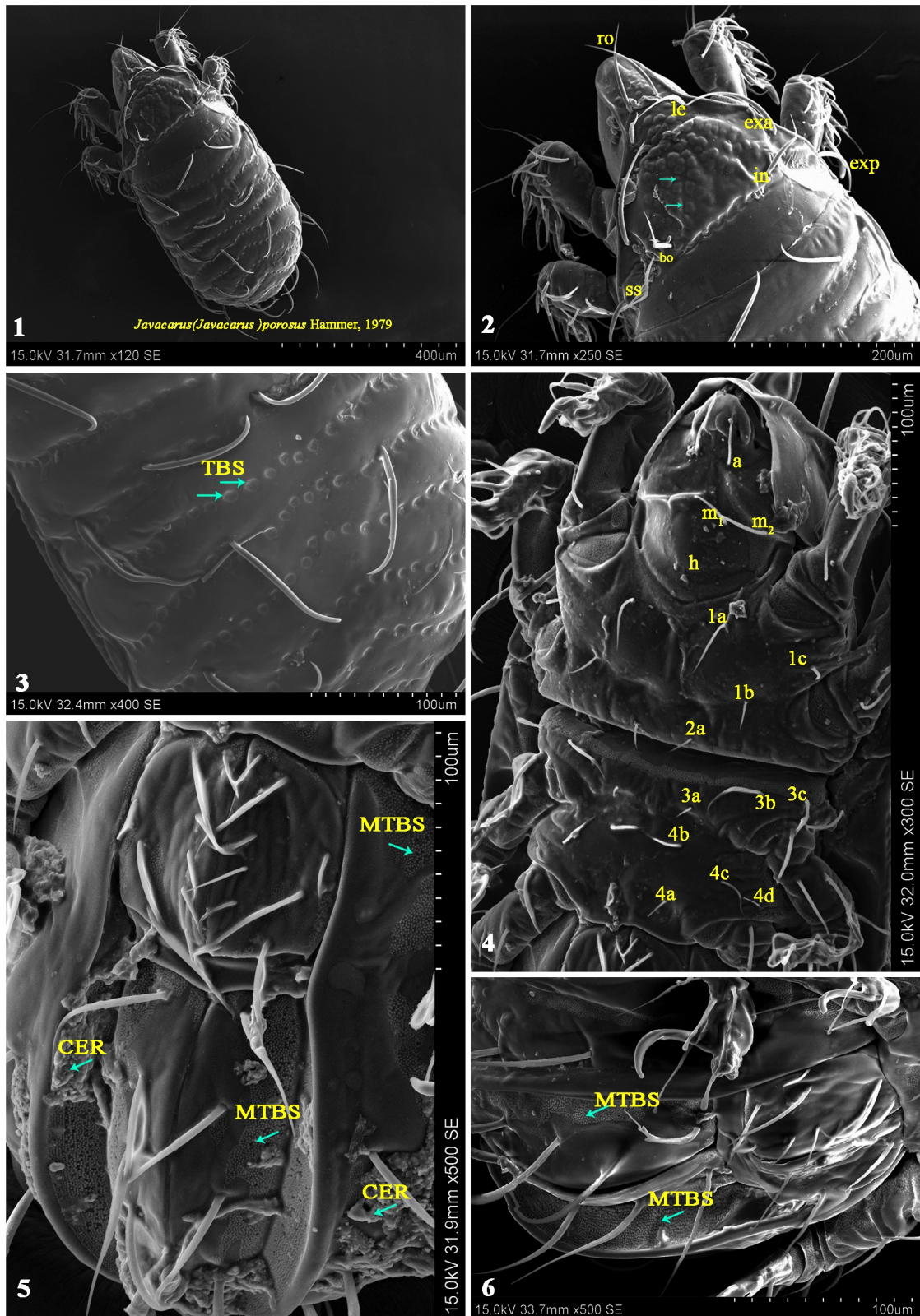


Fig. 1. Dorsal View; **2.** Enlarged View of Prodorsum Showing, Rostral Seta (ro), Lamellar Seta (le), Inter-Lamellar Seta (in), Anterior Exobothridial Setae (exa), Posterior Exobothridial Setae (exp), Sensillus (ss), Bothridium (bo); **3.** Notogaster with Tubercles (TBS); **4.** Ventral View: Showing Infracapitular and Epimeral Setae; **5.** Enlarged View of Ano-Adanal Plates Showing, thick Cerotegument (CER) and Microtubercles (MTBS); **6.** Microtubercles on the Lateral side of Ano-Adanal plates.

***Acrotritia clavata* (Märkel, 1964)**

***Acrotritia clavata* (Märkel, 1964)**

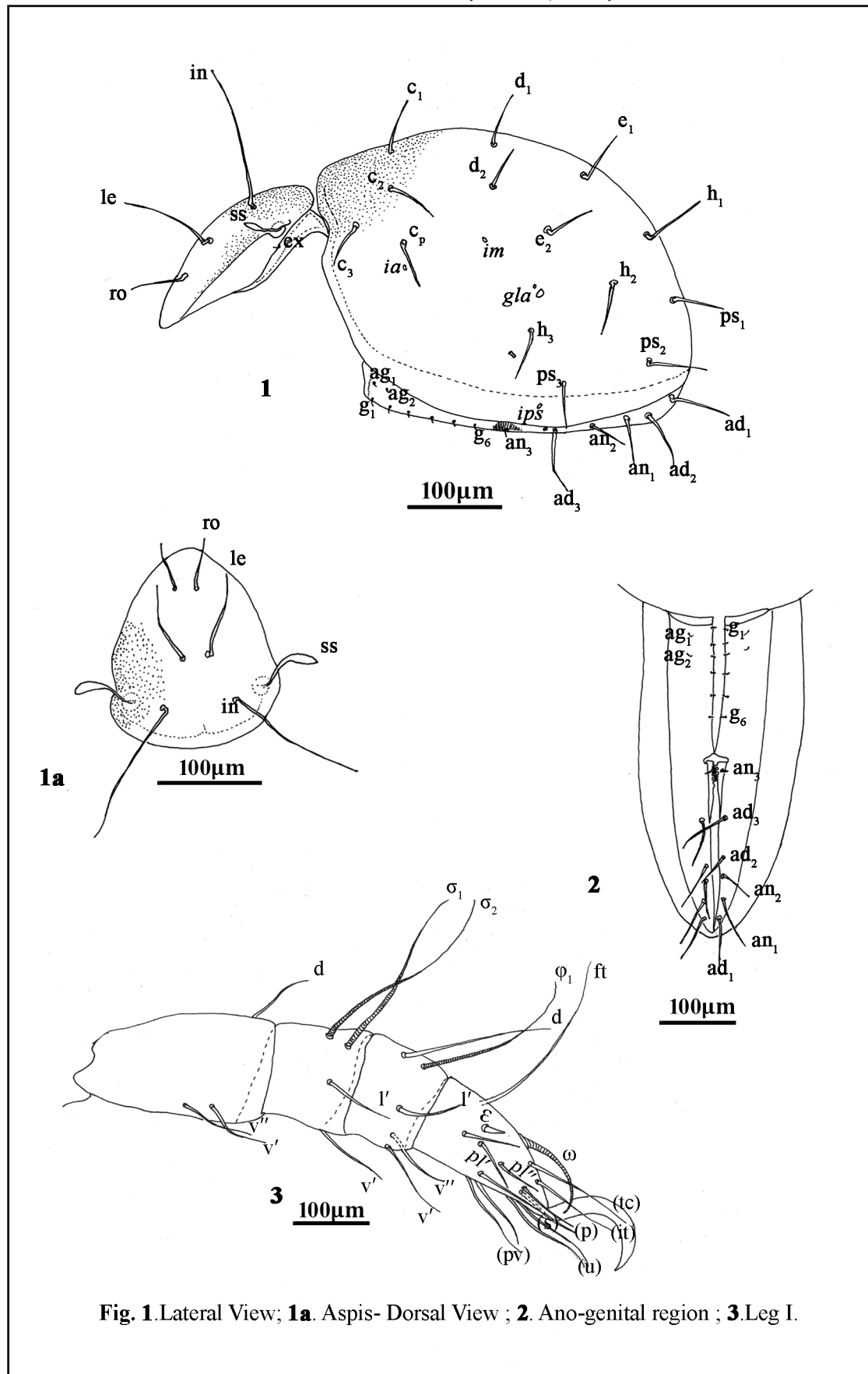


PLATE 22
Acrotritia clavata (Märkel, 1964)

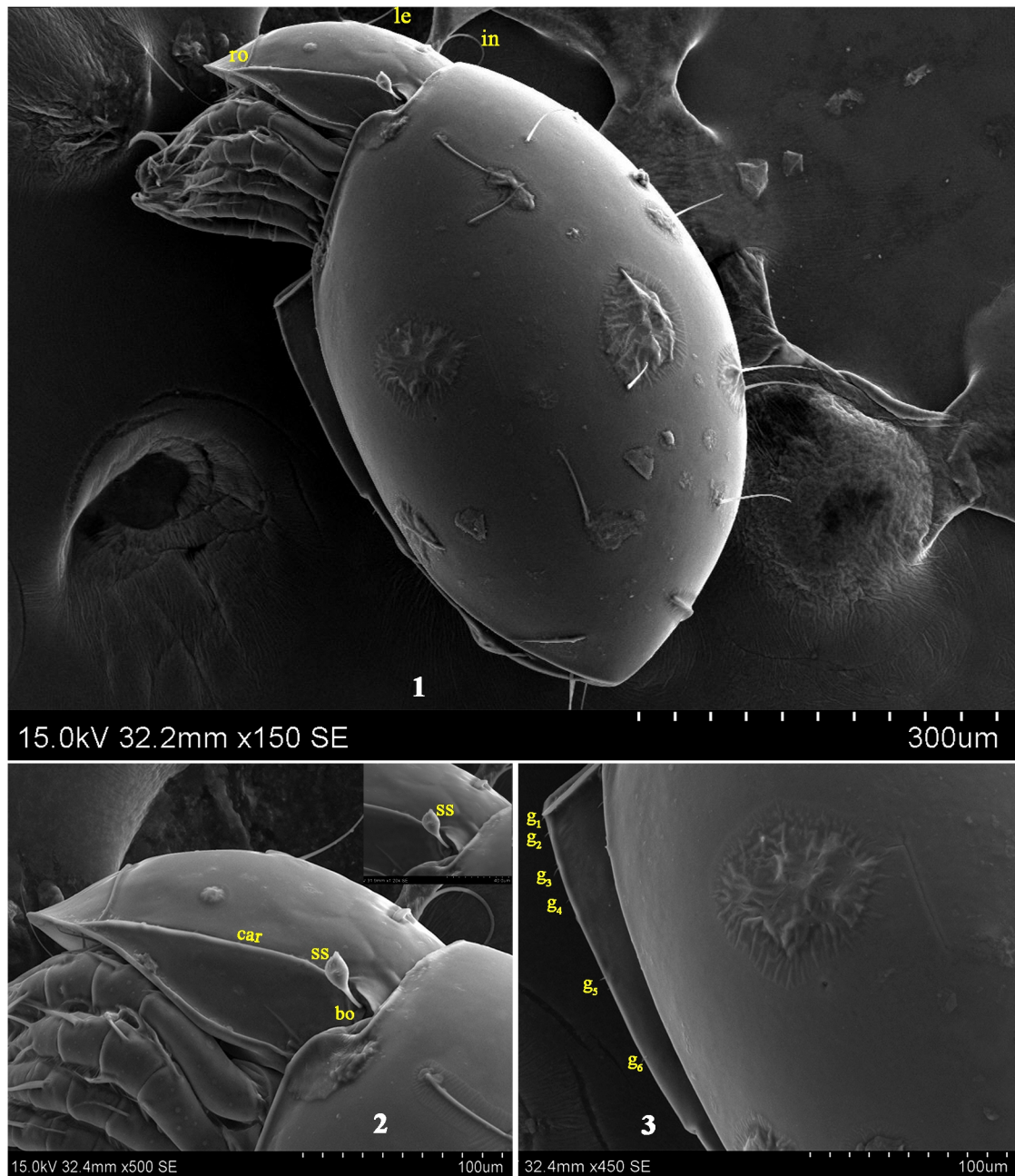


Fig.1.Lateral View- Aspis Showing Prodorsal Setae (in, le & ro); **2.** Enlarged View of Aspis Showing Clavate Sensillus (ss); Bothridium (bo) and Lateral Carina(car);**3.**Geni Plate with 6 Pairs of Small fine Genital Setae (g_1 - g_6).

PLATE 23

Hoplophorella (Hoplophorella) vitrina (Berlese, 1913)

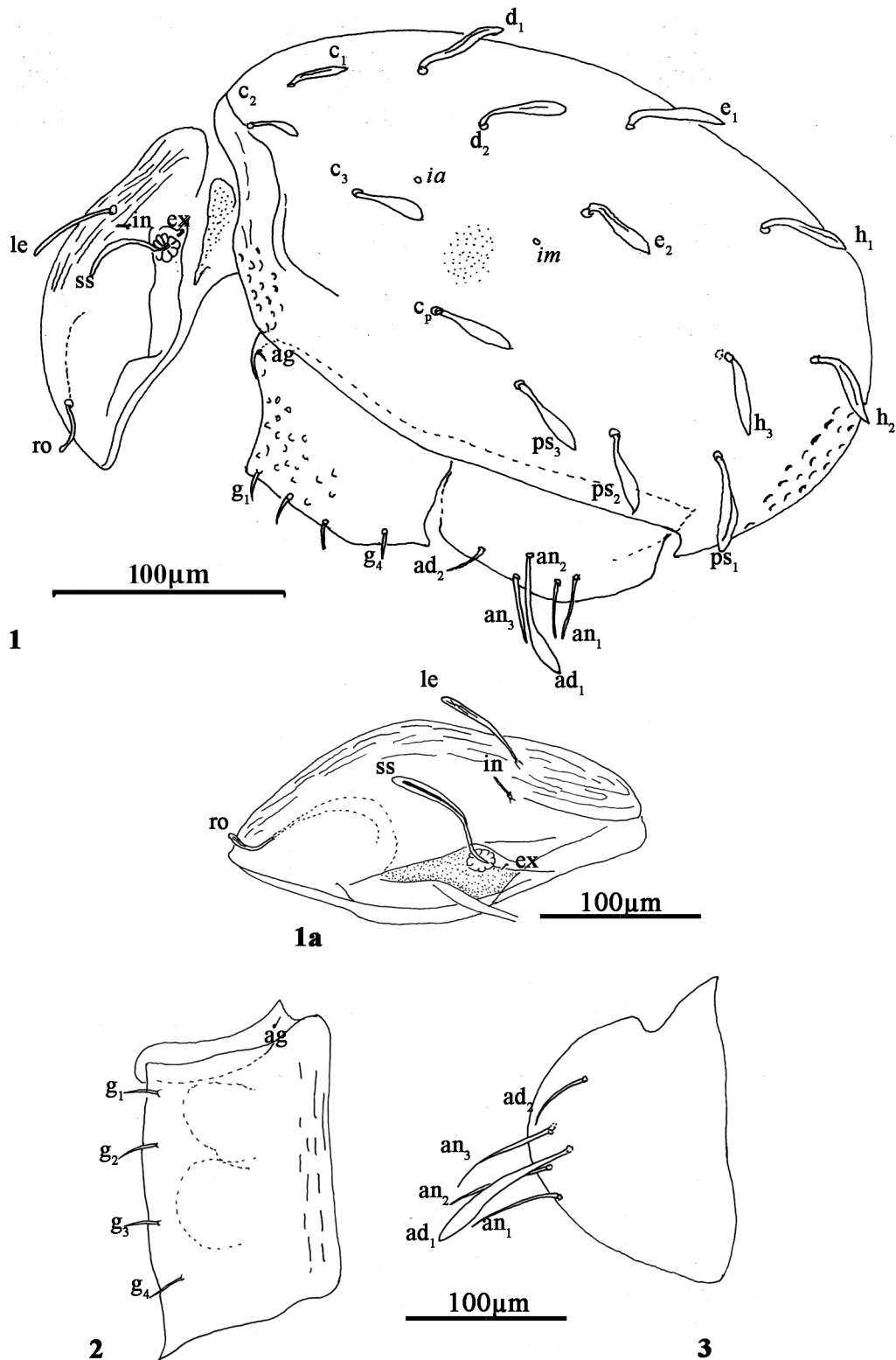
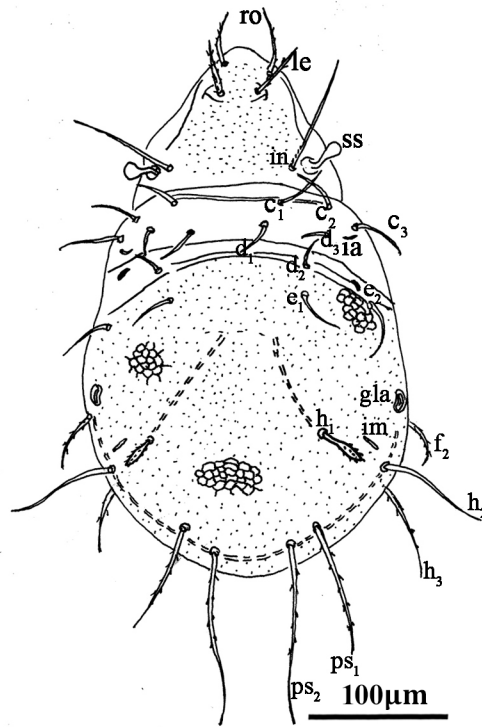


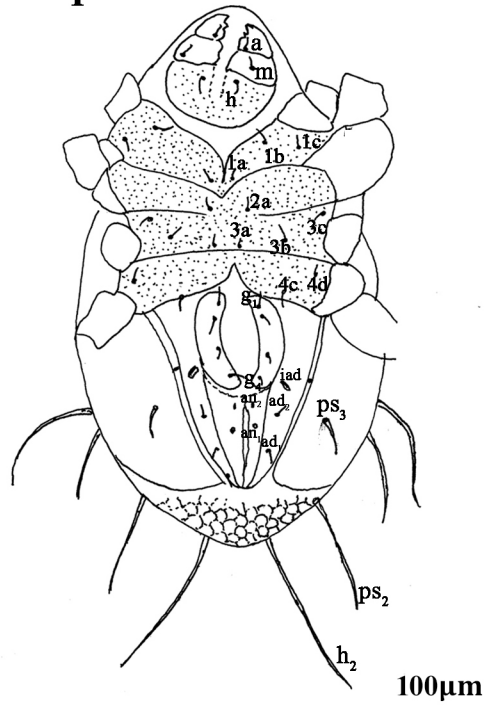
Fig.1. Lateral View; **1a**. Aspis-Lateral View; **2**. Genital Plate; **3**. Ano-Adanal plate.

PLATE 24

Afronothrus arboreus Ramani & Haq, 1992



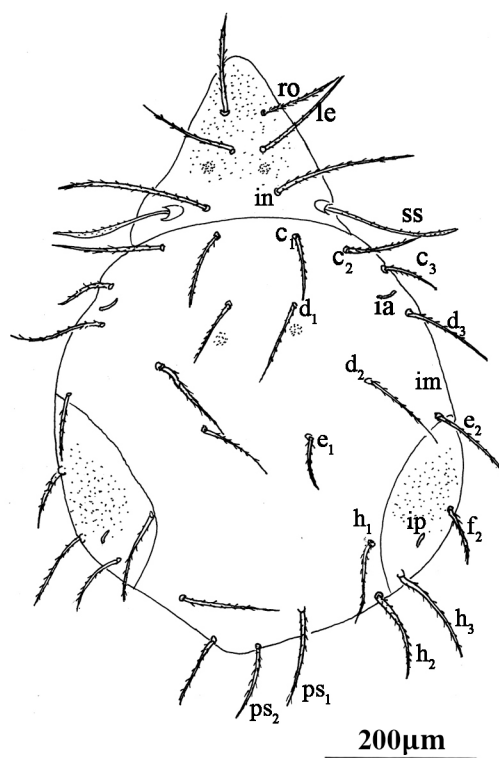
1



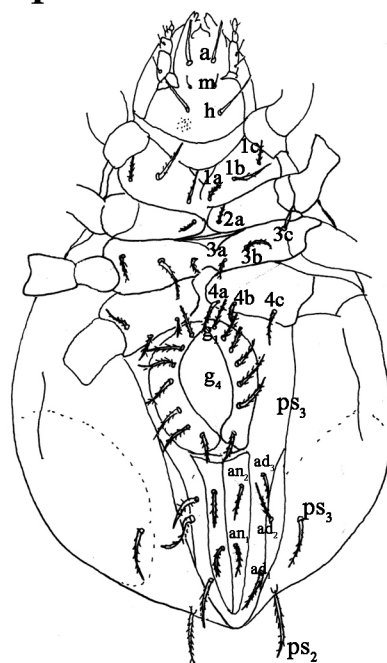
2

Fig. 1. Dorsal View; 2. Ventral View.

PLATE 25
Archegozetes longisetosus Aoki, 1965



1



2

Fig. 1. Dorsal View; 2. Ventral View.

PLATE 26

Carabodes (Klapperiches) penicillus (Mahunka, 1998)

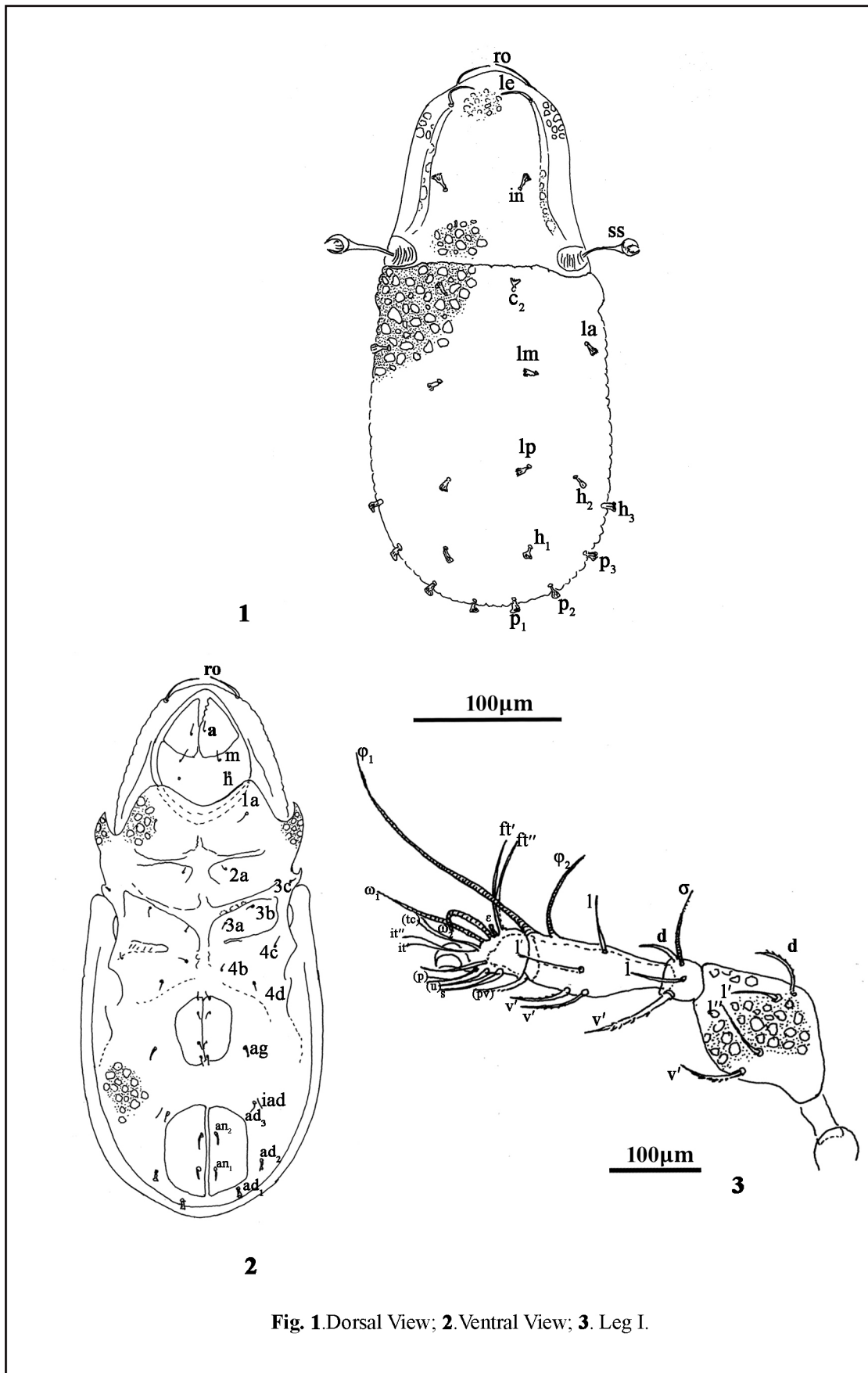


PLATE 27

Selenoribates mangrovius sp.nov.

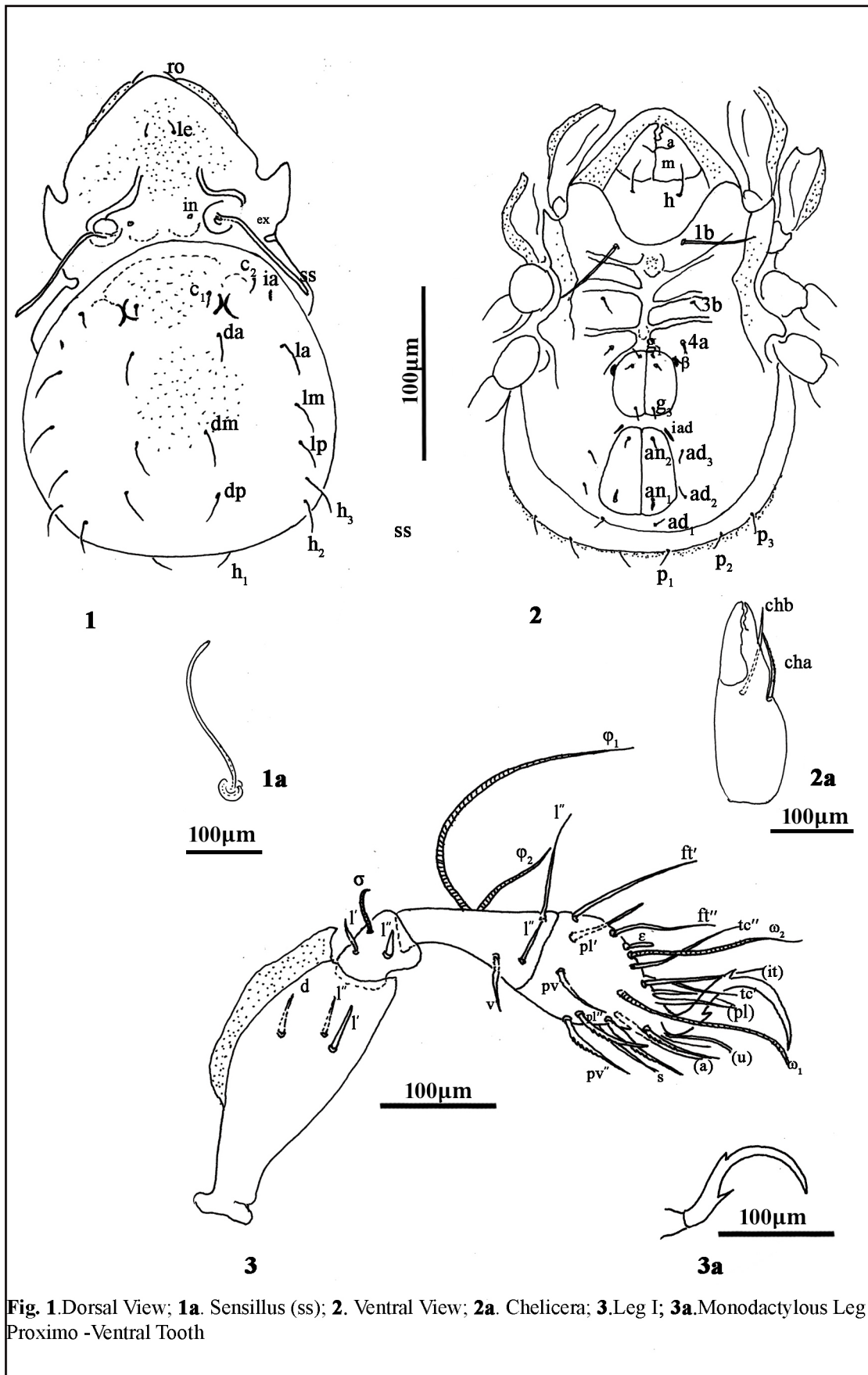


Fig. 1. Dorsal View; **1a.** Sensillus (ss); **2.** Ventral View; **2a.** Chelicera; **3.** Leg I; **3a.** Monodactylous Leg Proximo-Ventral Tooth

PLATE 28

Holocarinozetes gen. nov.; *Holocarinozetes epimeratus* gen.nov.sp.nov.

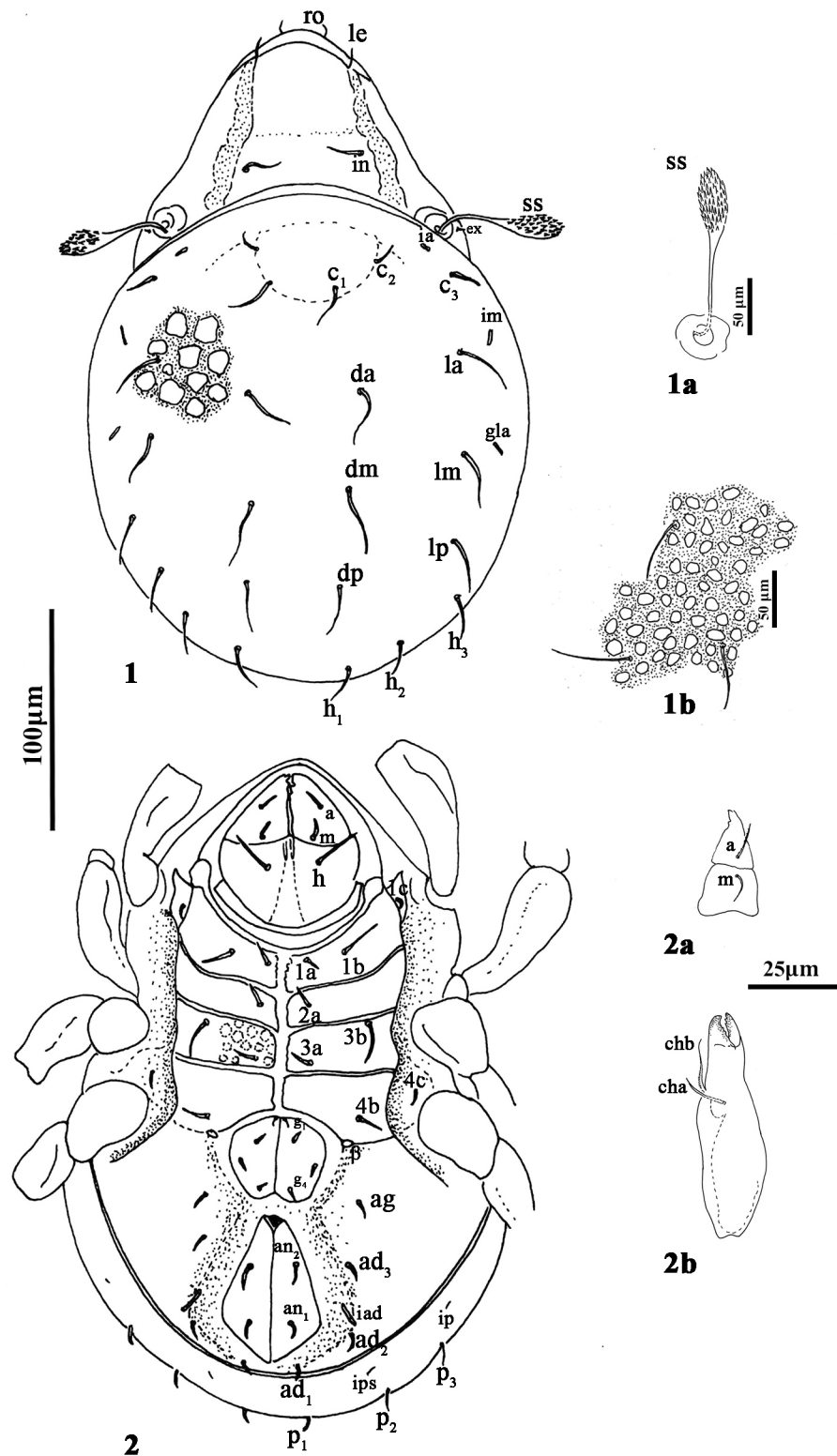


Fig.1. Dorsal View; **1a.** Sensillus (ss); **1b.** Enlarged View of Notogastral Integument; **2.** Ventral View; **2a.** Infracapitulum; **2b.** Chelicera

PLATE 29
H. epimeratus gen.nov.p.nov.

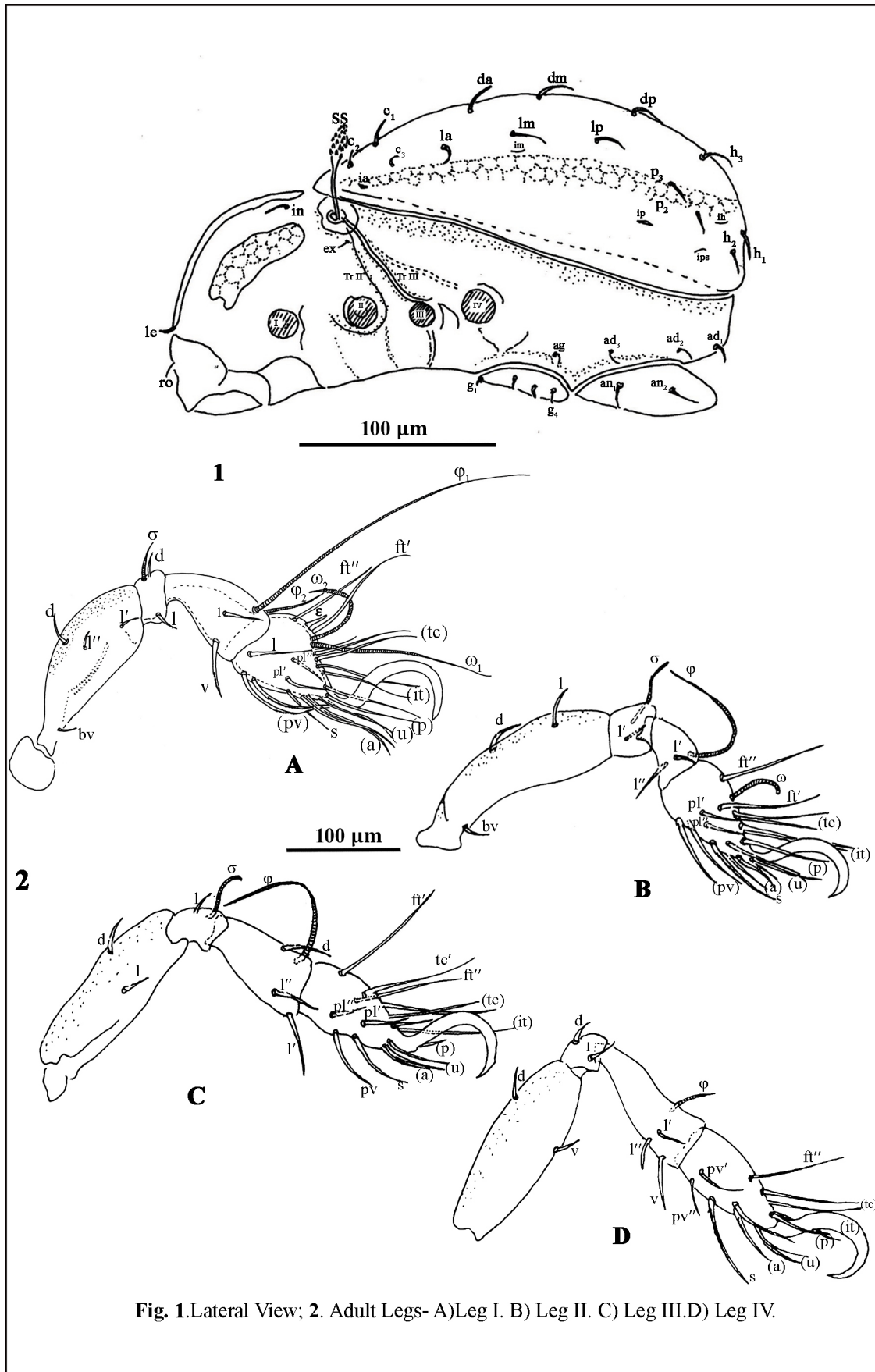


Fig. 1. Lateral View; **2.** Adult Legs- **A)** Leg I. **B)** Leg II. **C)** Leg III. **D)** Leg IV.

PLATE 30
H. epimeratus gen.nov.sp.nov.

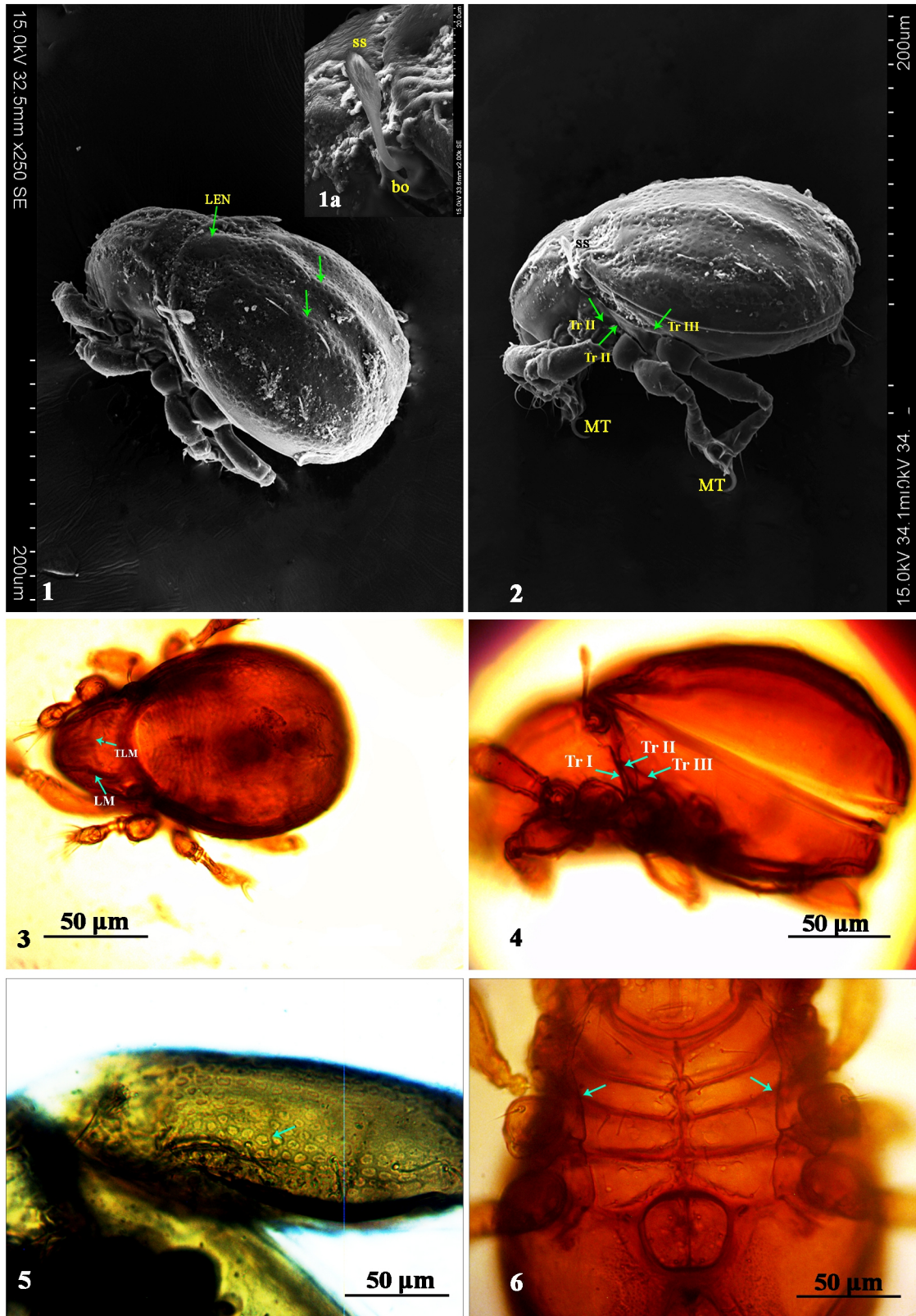


Fig.1.Dorsal View Showing Lenticulus (LEN), Two parallel Convex, Hump- like Notogastral ridges (Arrow); **1a.** Club- Shaped Sensillus (ss) and Laterally Opened Bothridium (bo); **2.**Lateral View-showing van der Hammen's organ and Acetabular Tracheae (Tr I-III)**3.** Dorsal view- showing lamellae (LM) and trans- lamella(TLM);**4.** Lateral View showing Acetabular Tracheae (Tr I& III); **5.** Notogastral Integument; **6.**Ventral View Showing Characteristic pair of Ventral Carinae Running from Epimere I-IV (Arrow)

PLATE 31

Lamellobates (Lamellobates) molecula (Berlese, 1916)

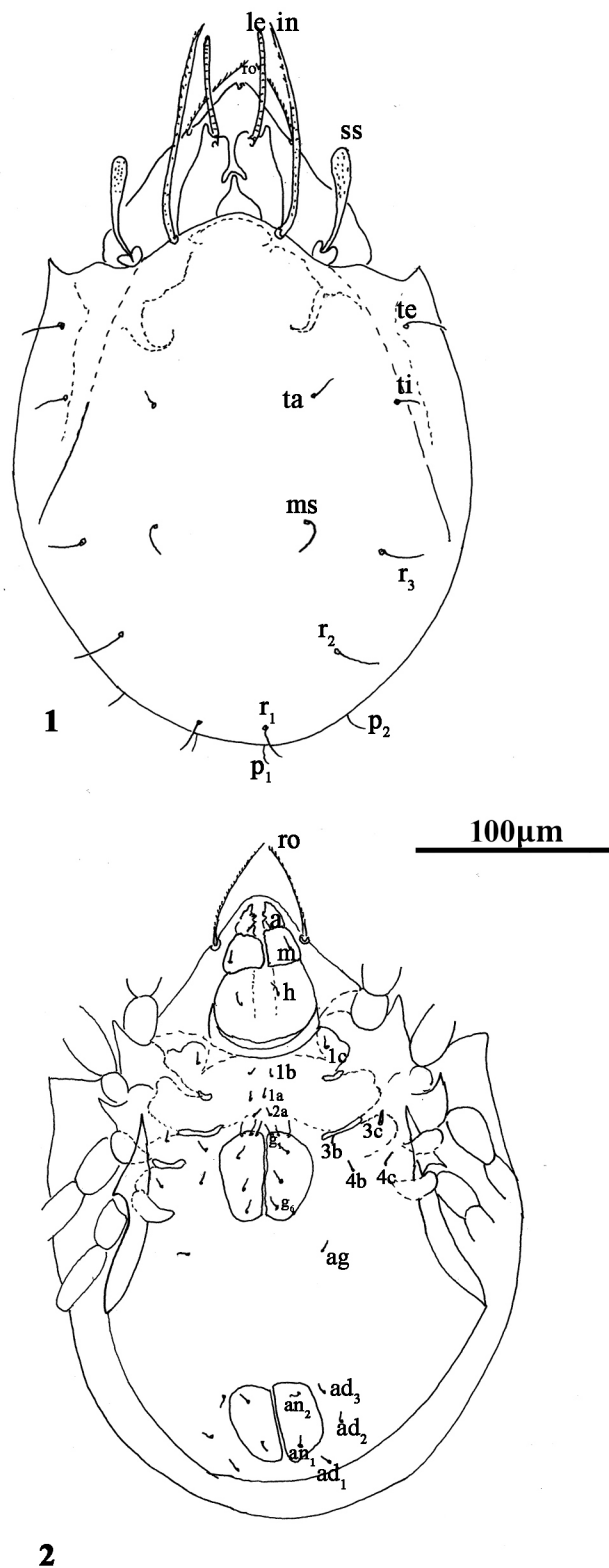
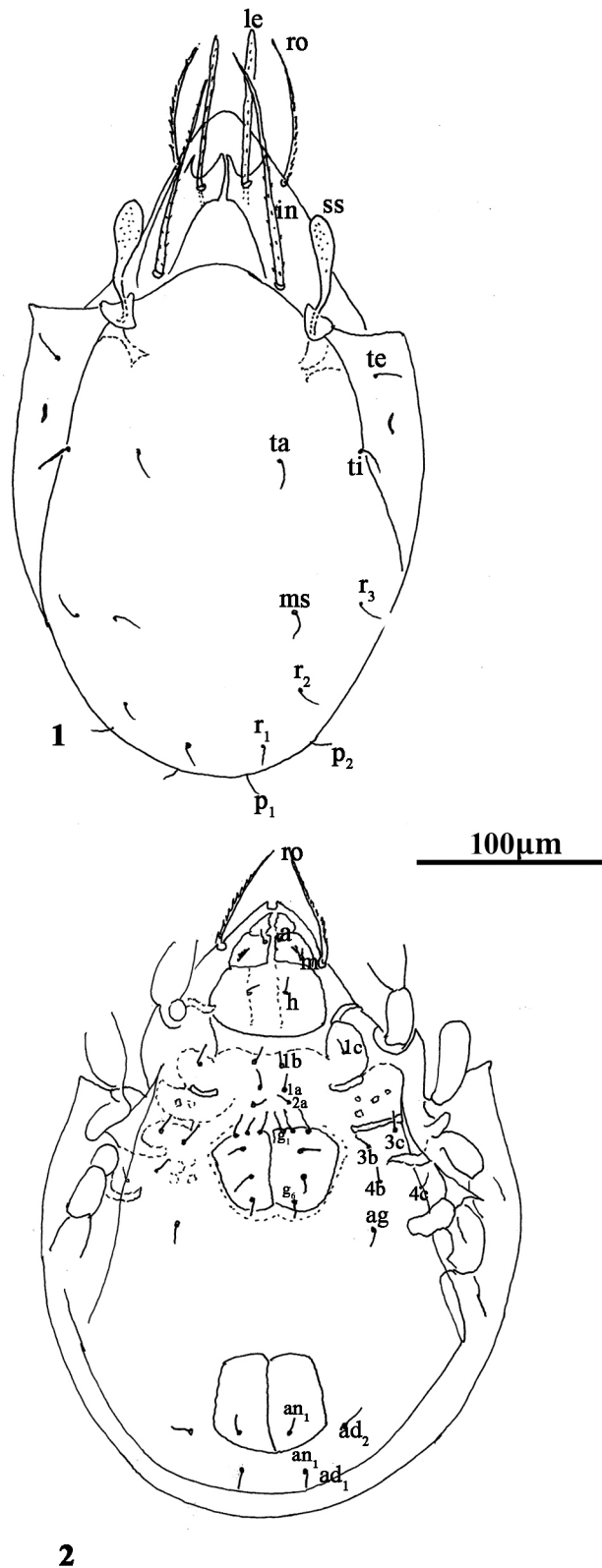


Fig. 1.Dorsal View;2. Ventral View

PLATE 32

Lamellobates (Paralamellobates) bengalensis Bhaduri & Raychaudhuri, 1968



2

Fig.1.Dorsal View; 2. Ventral View.

PLATE 33

Phauloppia kadalundiensis sp.nov.

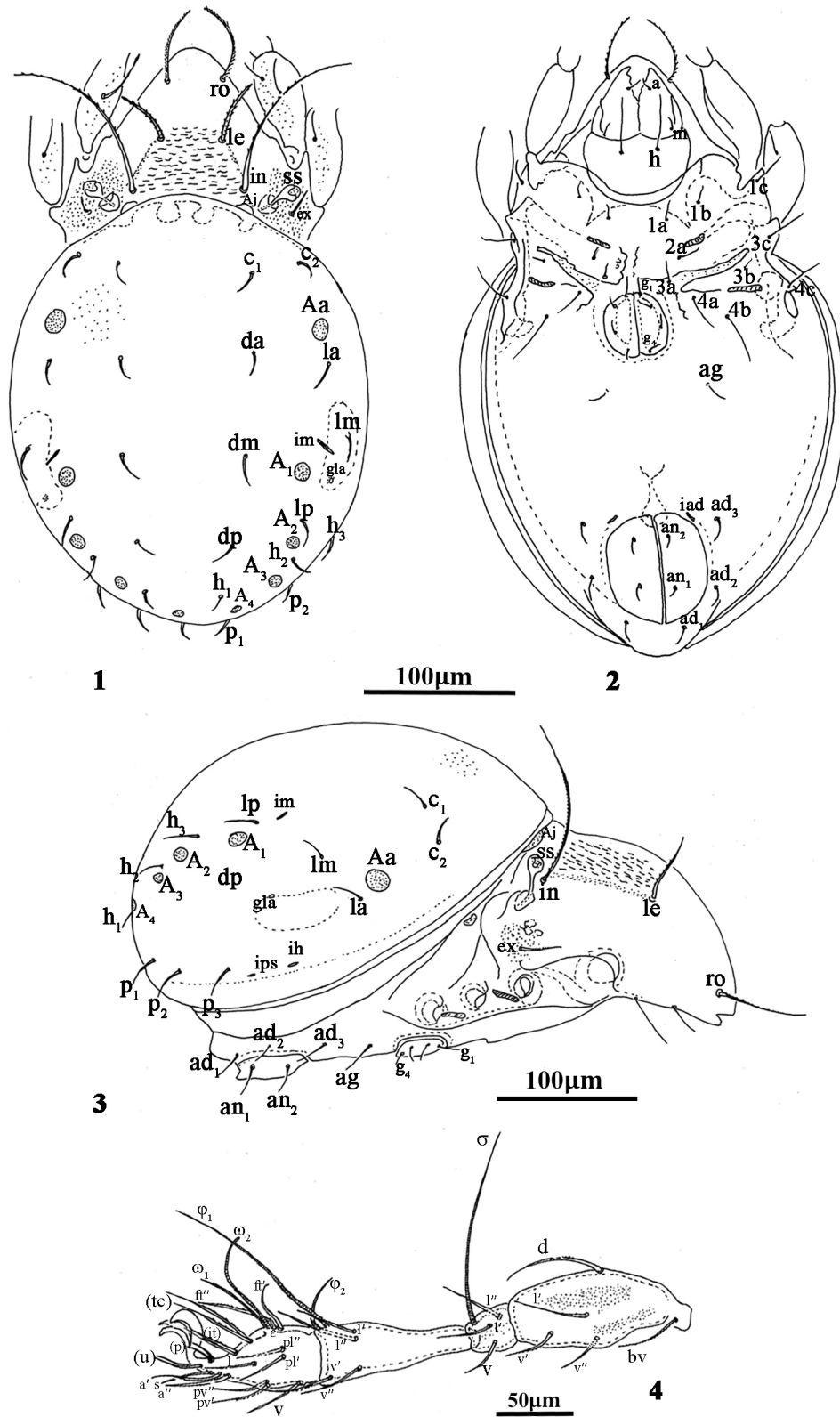
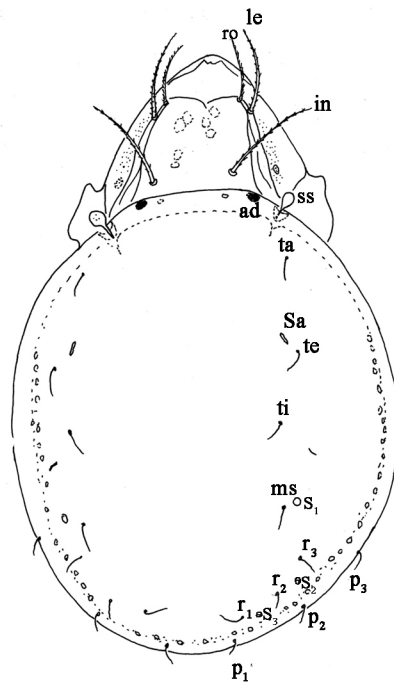


Fig.1. Dorsal View; 2. Ventral View; 3. Lateral View; 4. Leg I.

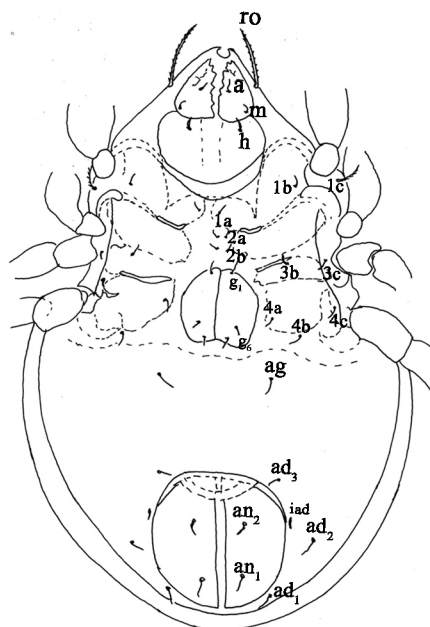
PLATE 34

Siculobata (Siculobata) malabarica Ramani & Haq, 1998

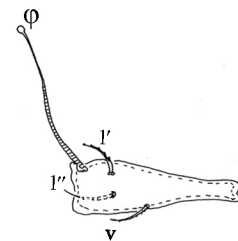


1

100µm



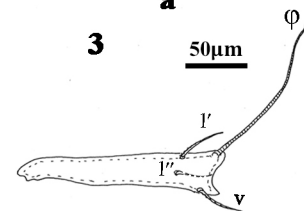
2



a

3

50µm

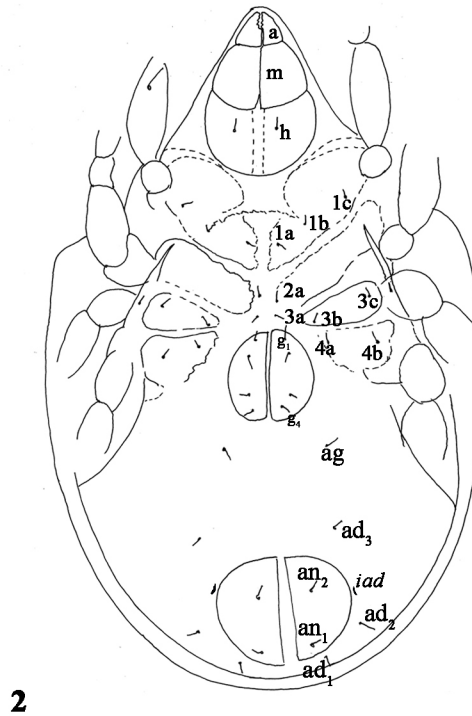
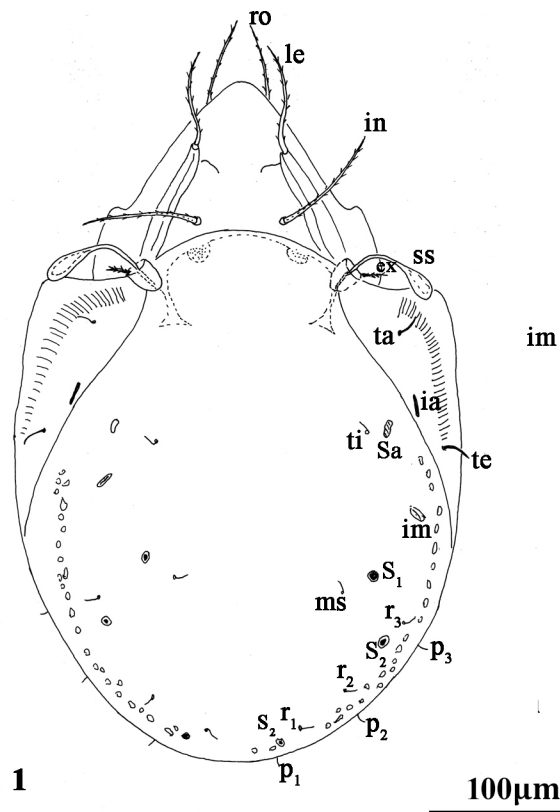


b

Fig.1. Dorsal View; 2. Ventral View; 3. a. Tibia III, b. Tibia IV

PLATE 35

Scheloribates (Scheloribates) praeincisus interruptus (Berlese, 1916)



2

Fig.1- Dorsal View; 2. Ventral View

PLATE 36

Protoripoda (Protoripoda) trifolius sp.nov.

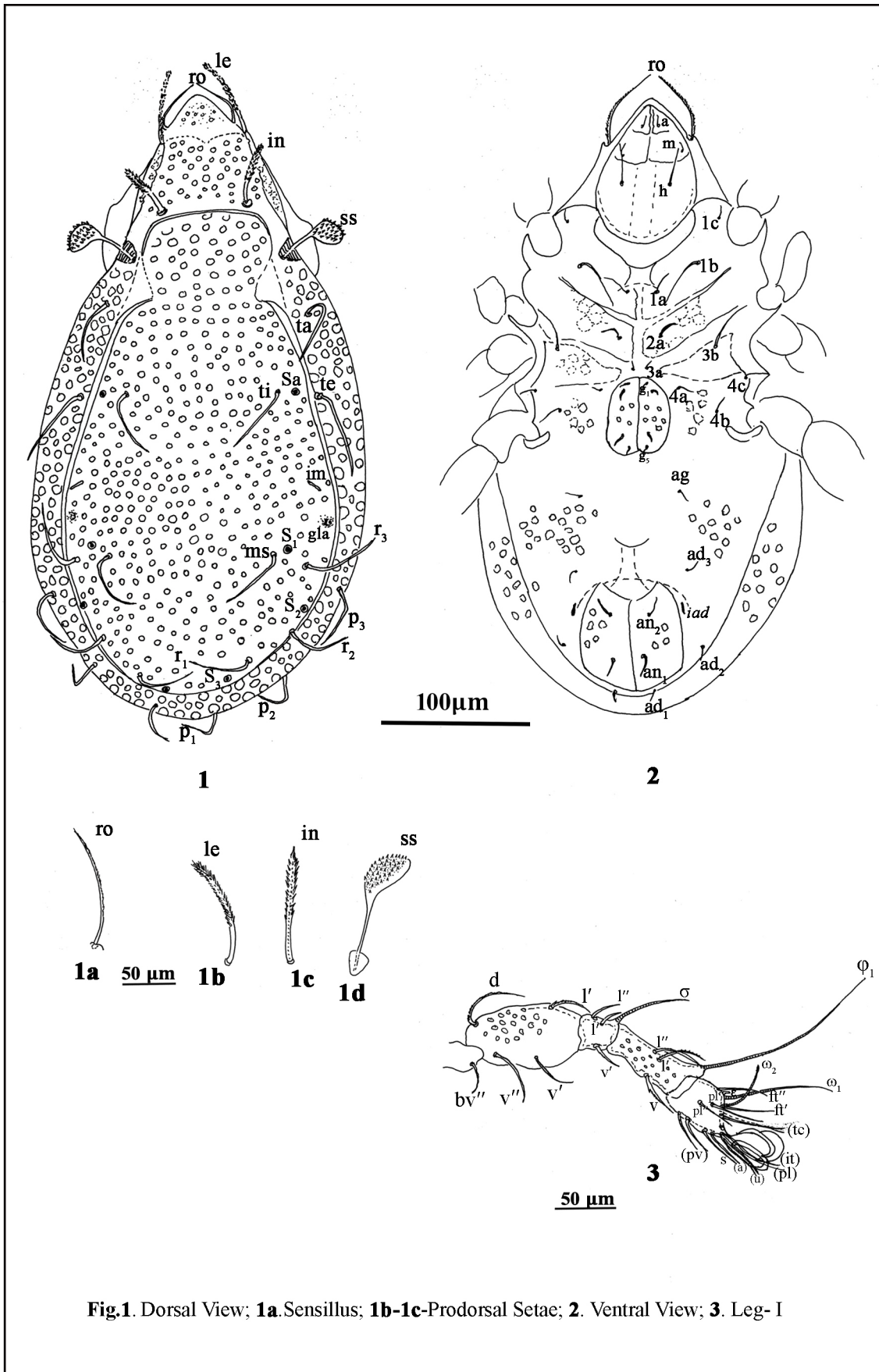


PLATE 37

Protoribates (Protoribates) capucinus Berlese, 1908

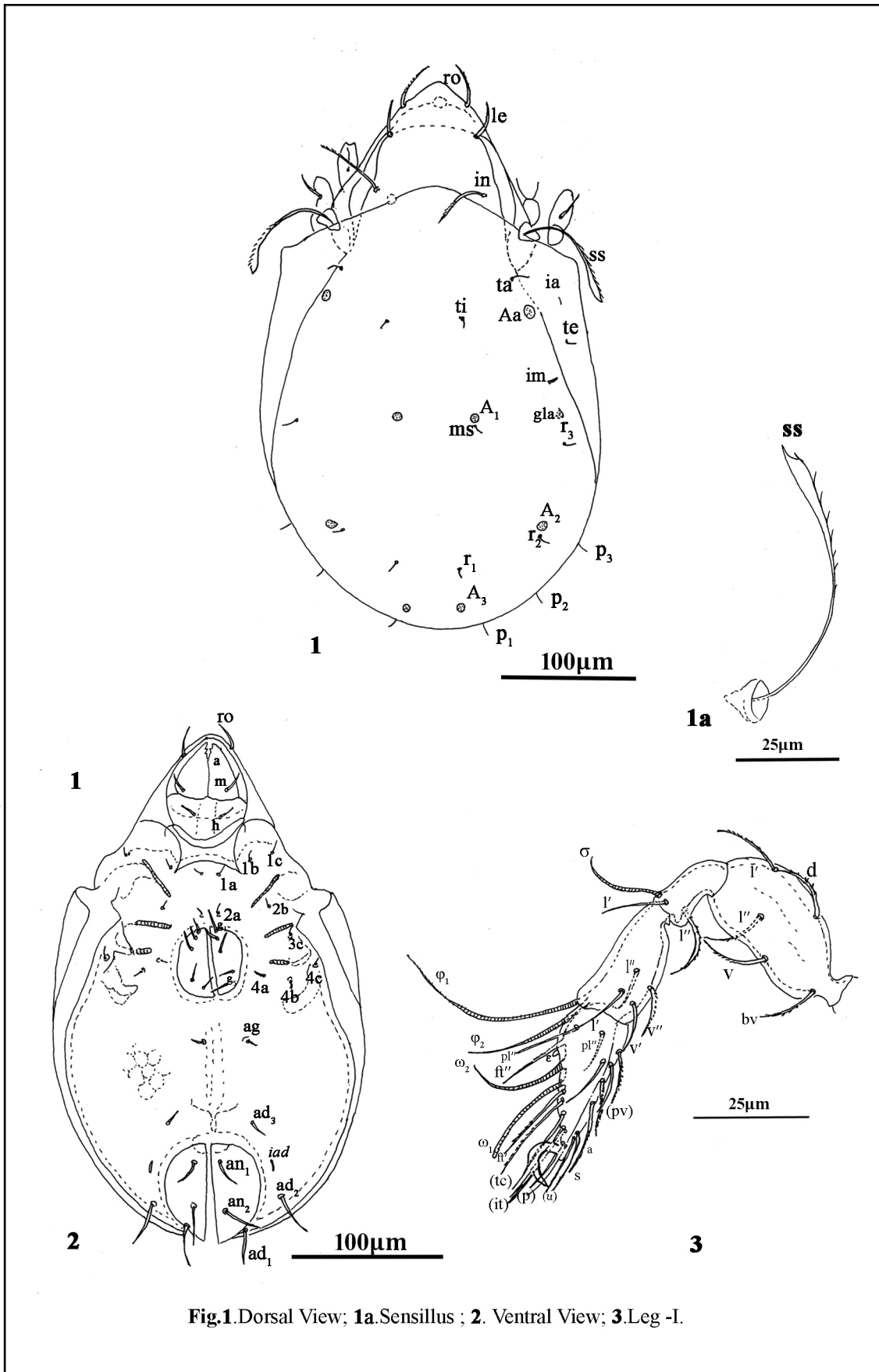


Fig.1.Dorsal View; 1a.Sensillus ; 2. Ventral View; 3.Leg -I.

PLATE 38

Indoribates(Indoribates) punctulatus (Sellnick, 1925)

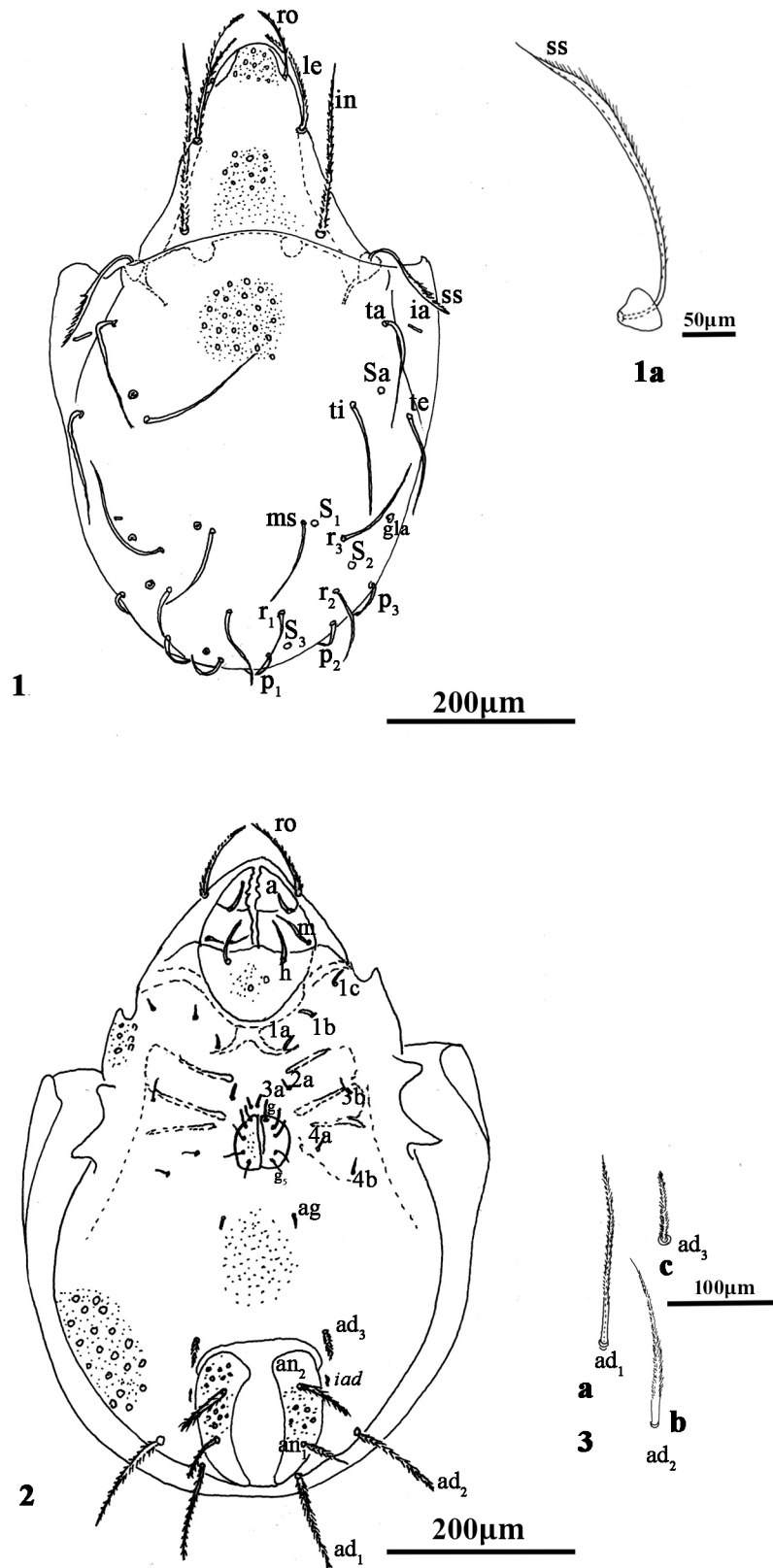


Fig.1. Dorsal View; 1a. Sensillus; 2. Ventral View; 3. Adanal setae, ad₁-ad₃

PLATE 39

Indoribates(Indoribates) punctulatus (Sellnick, 1925)

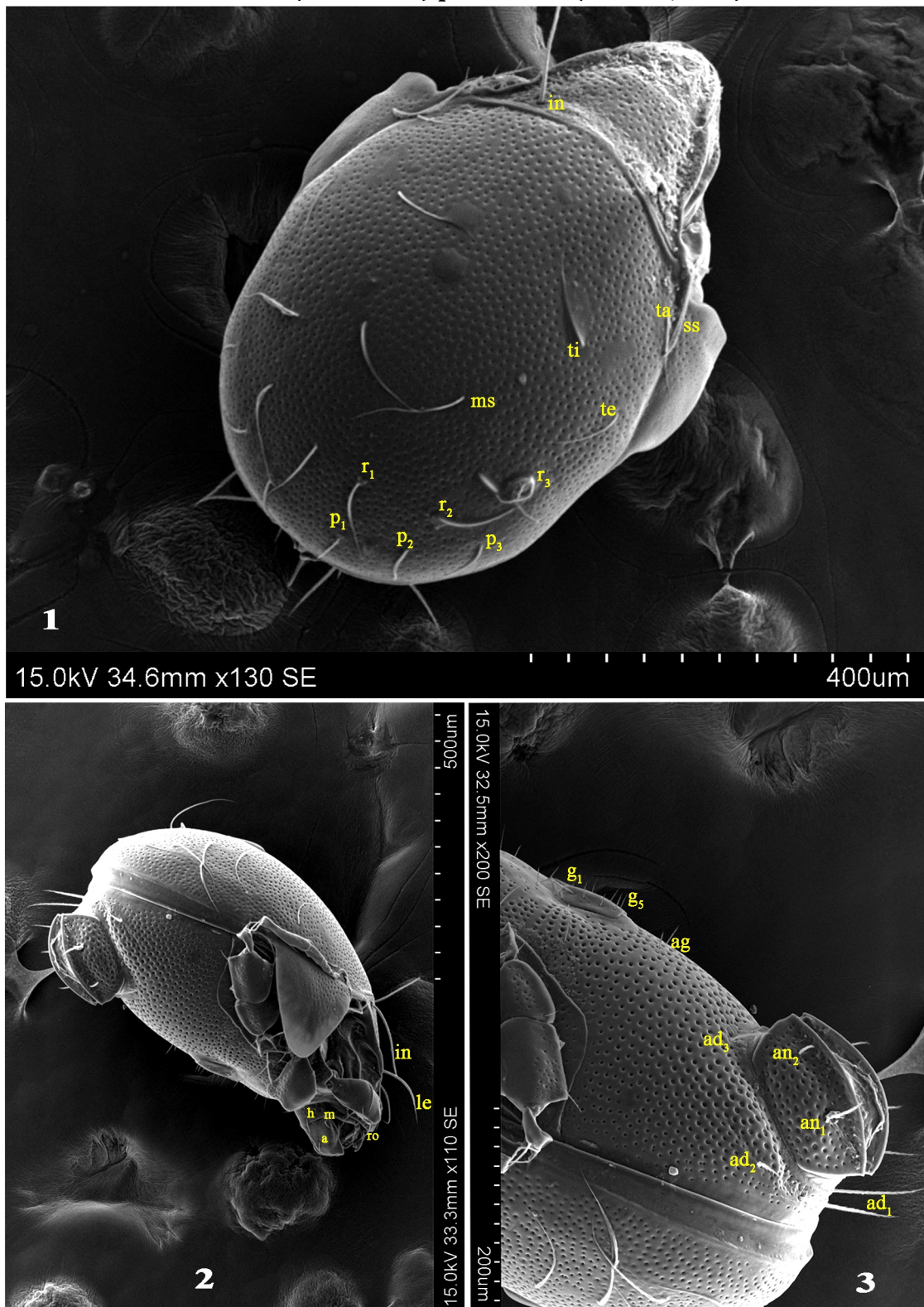
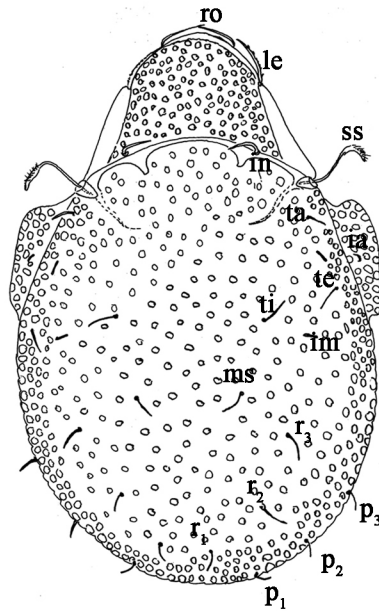


Fig.1.Dorsal View; **2.**Lateral View; **3.** Ventral View -Ventral Region Showing Foveoles and Pits; Genital Setae (g₁-g₅), Aggenital Setae (ag), Anal setae (an₁ & an₂) and Adanal Setae (ad₁-ad₃)

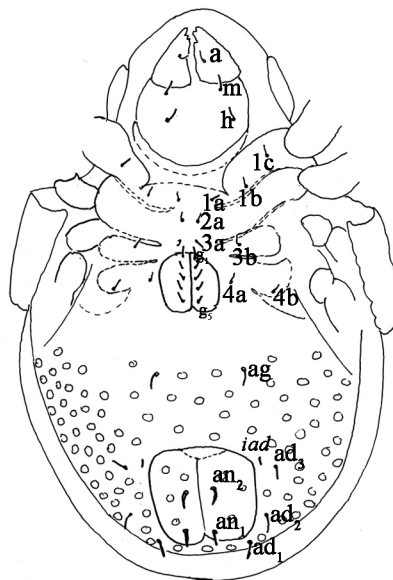
PLATE 40

Trachyoribates (Rostrozetes) ovulum ovulum Berlese, 1908



1

100μm



2

100μm

Fig.1.Dorsal View; 2.Ventral View

PLATE 41

Trachyoribates (Rostrozetes) nortonii sp.nov.

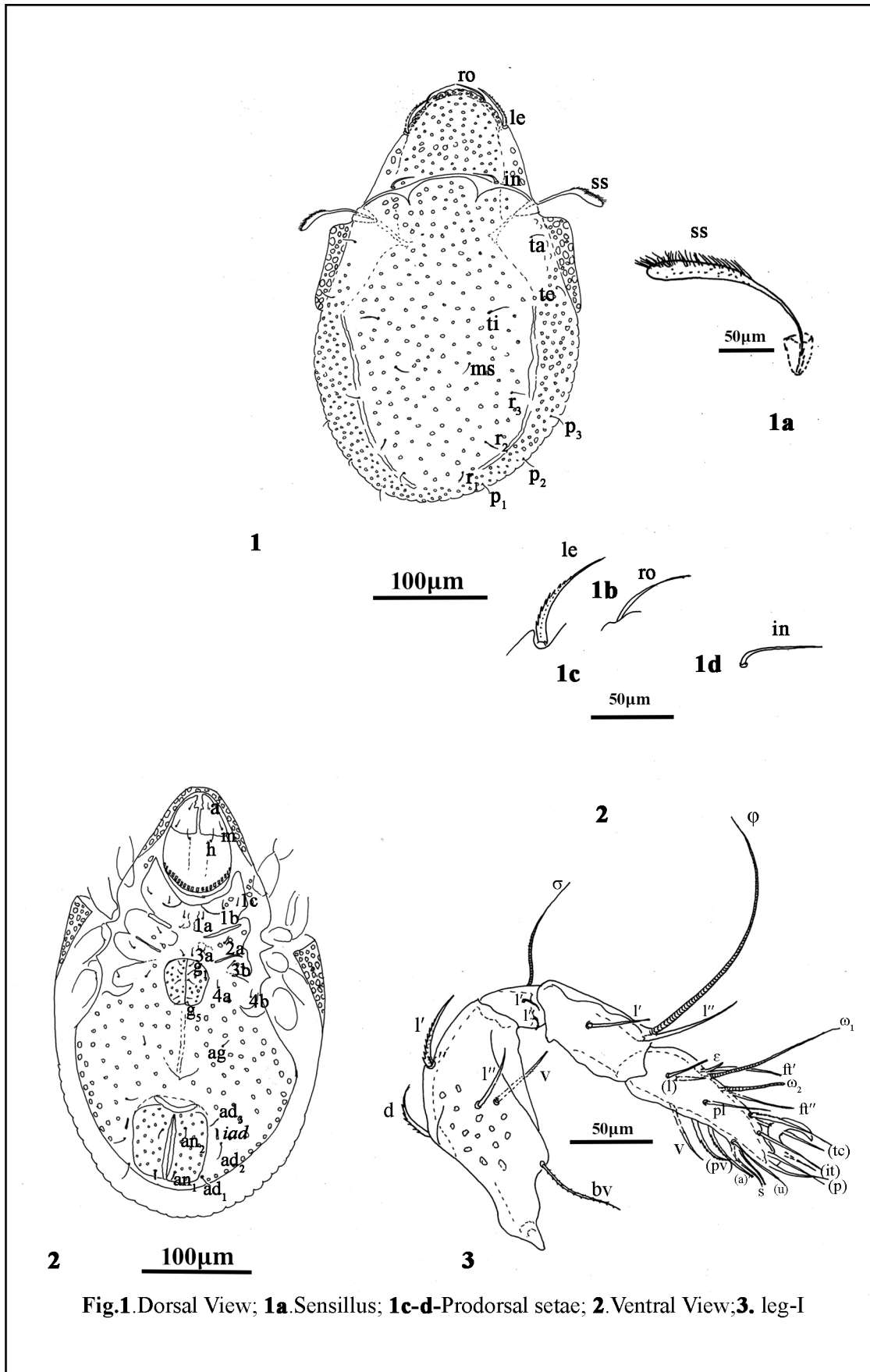


PLATE 42

Galumna (Galumna) paragibbula Weigmann, 2011

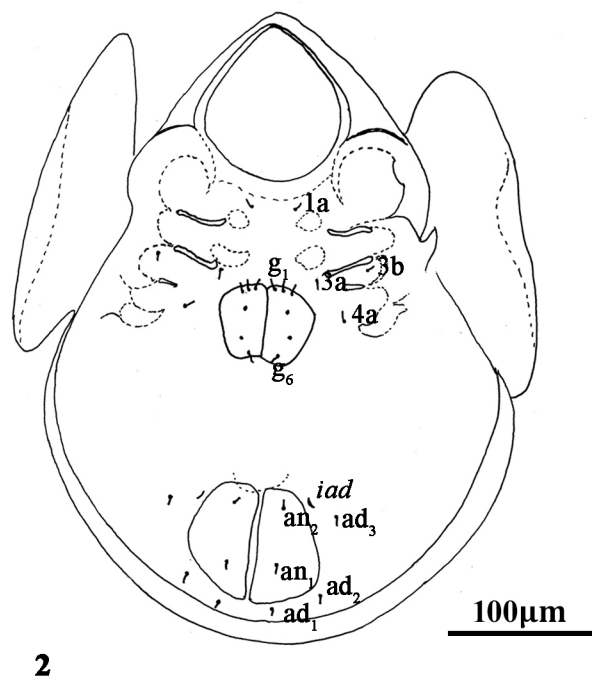
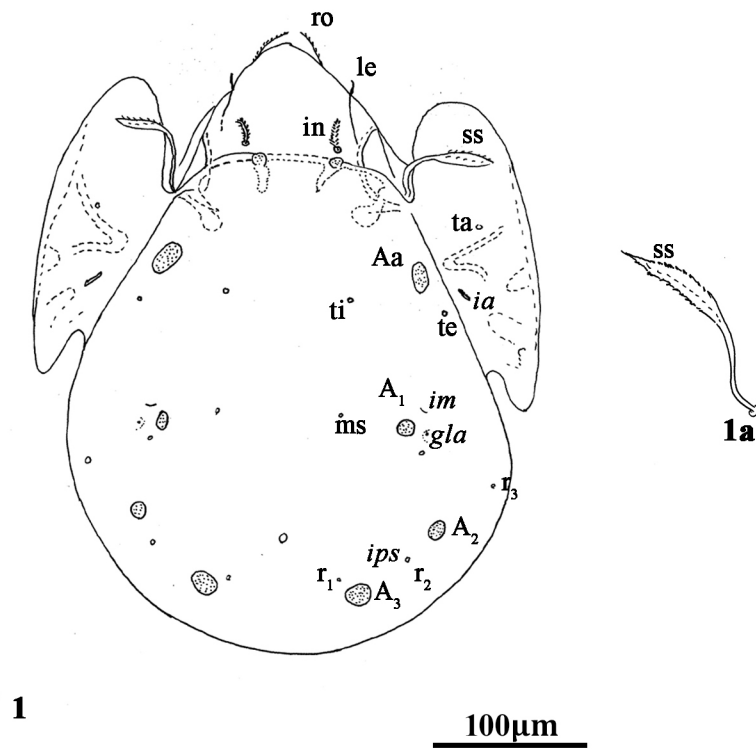


Fig.1. Dorsal View; **1a.** Sensillum; **2.** Ventral View

PLATE 43

Materials and Methods: Food Choice Test and Developmental Studies



Fig.1. SEM image of *Acrotitia clavata* ; 2. Culture cell with Caferia: a. Bark of *A.marina* with green alga, *Microspora* sp.; b. Dried Moistened Pneumatophore; c. Dried Moistened Leaves of *A. marina* ; d. Dried Moistened Leaves of *A. ilicifolius*; 3. Dried Moistened Pneumatophore Section Showing a. Pith; b. Pericycle; c. Gas- filled Aerenchymatous Tissues; d. Epidermis; 4. A single Culture Chamber Showing the Plaster of Paris- Charcoal base 5.Special Cultural Rings used for Developmental Studies. 6.Culture Chambers (CC).

PLATE 44

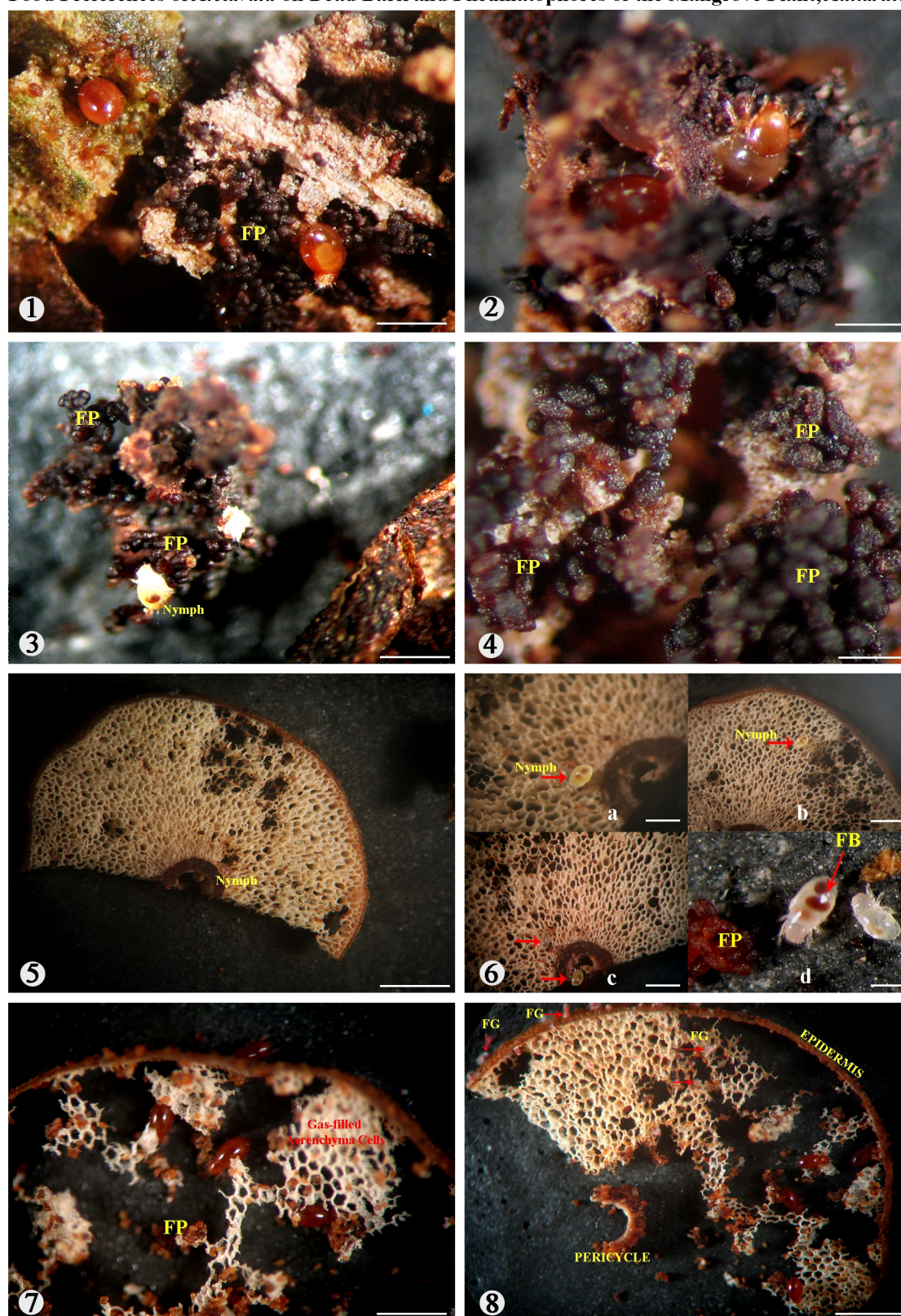
Feeding habits of *Acrotritia clavata* on dead components of the mangrove plant, *Avicennia marina*



Figs.1&2. Aggregation of *A.clavata* on the dead bark of *A. marina* ;3. Progressive Feeding of *A.clavata* on bark of *A.marina* and Production of Brown Coloured Fecal Pellets(Arrow);4.Mass Production of Fecal Pellets on *Microspora* growing bark of *A.marina* ; 5.Feeding Activity of *A.clavata* (nymph) on the Decayed *Microspora* filament; 6. Boring and Tunnelling Activity of *A.clavata* on the Decomposed twig of *A. marina* 7. Accumulation of Fecal Pellets (FP) on Feeding Substrates ;8.Brown and Green (Arrow) Coloured Fecal pellets Produced by *A.clavata* in the Culture Cells.(Scale bar = 1mm)

PLATE 45

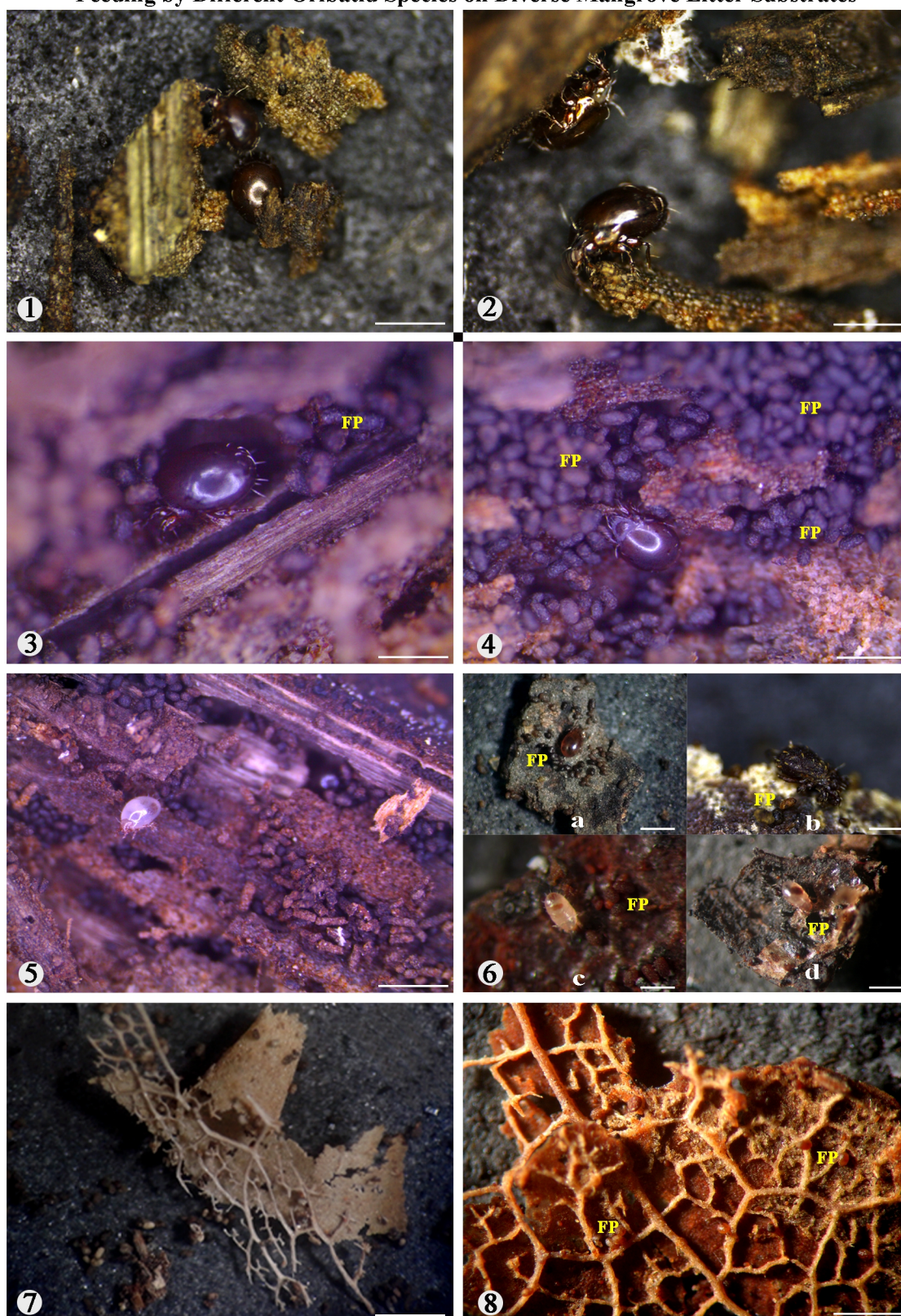
Food Preferences of *A.clavata* on Dead Bark and Pneumatophores of the Mangrove Plant, *A.marina*



Figs.1&2. Boring and Tunnelling Activity of *A.clavata* on the Decomposed barks *A. marina* and Accumulation of brown and Fecal Pellets (FP); 2-4. Nymph Feeding on dead leaves of *A. marina* and production of Black Coloured Fecal Pellets (PC); 5-6c. Active Feeding of Larval and Nymphal Stages (Arrow) along the region of cortex (Gas- filled Aerenchyma Cells); 6d. Nymph with Brown Coloured Food Boli (FB) Inside the Digestive Tract; 7. Feeding Preference on Gas- filled Aerenchyma Cells; 8. Rejection of Pericycle and Epidermis of the Pneumatophore by Mites and Fungal Growth (FG) on Unfed Remnants. (Scale bar= 1mm)

PLATE 46

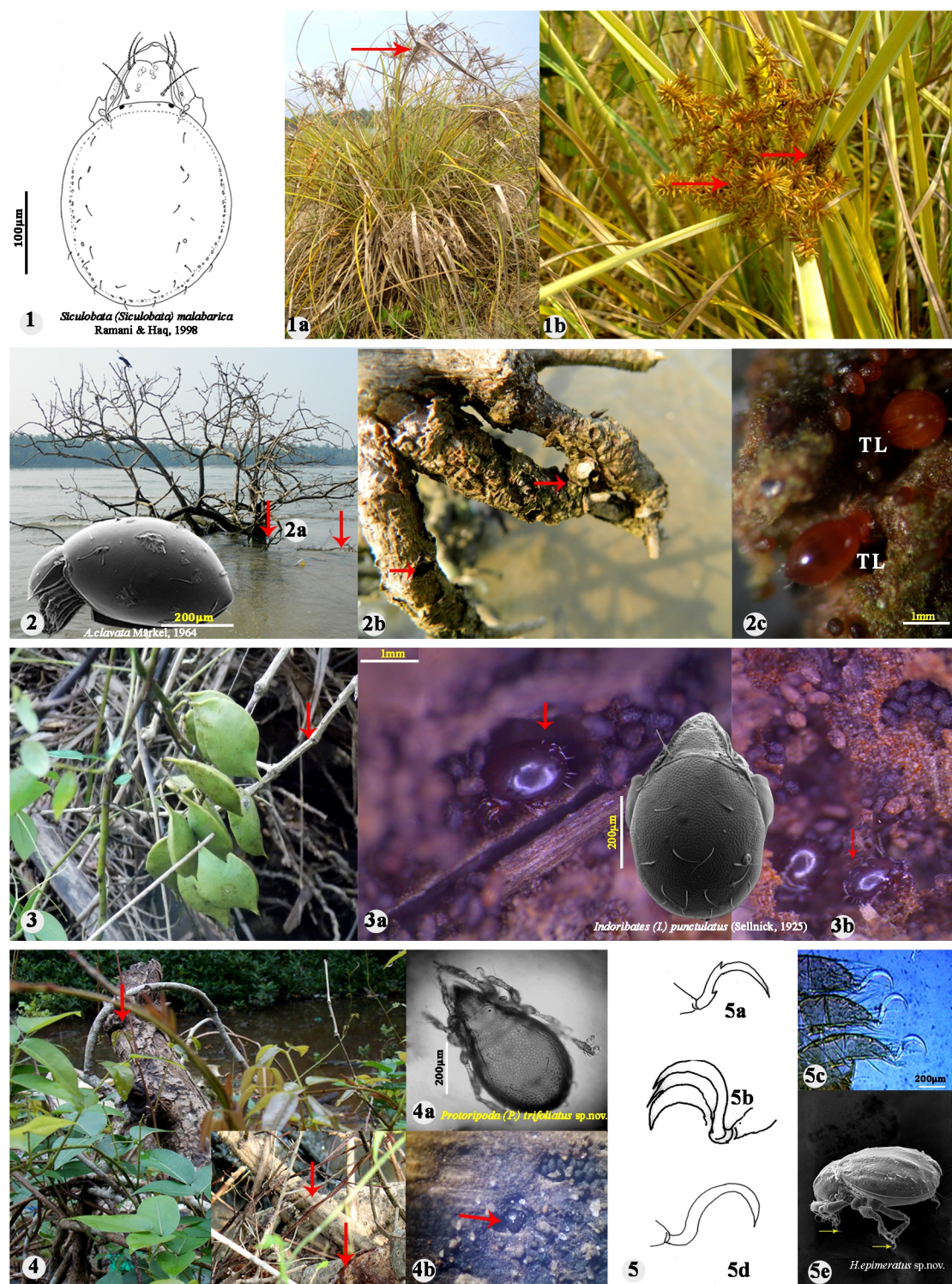
Feeding by Different Oribatid Species on Diverse Mangrove Litter Substrates



Figs. **1&2.** Feeding of *Indoribates. (I.) Punctulatus* on the dead bark of *C. crista* ; **3&4.** Active Feeding of *I. (I.) punctulatus* on bark of *C. crista* and Production of Black Coloured Fecal Pellets (FP); **5.** Boring and Tunnelling Activity of *I. (I.) punctulatus* on Decomposing Twigs of *C. crista*; **6.** Active Feeding and Production of Fecal Pellets (FP) by (a) *P. (P.) capucinus*, (b) *Nothrus* sp., (c) *J. (J.) porosus* and (d) Nymphs of *Indoribates. (I.) Punctulatus* on Different Mangrove Litter Components; **7&8.** Skeletonization of Leaf Tissues by Mite Feeding (Scale bar = 1mm).

PLATE 47

Microhabitat preference/ associations and morphological modifications in mangrove dwelling oribatids



Figs.1. *Siculobata (S.) malabarica*; 1a & b. Most preferred microhabitat, Spikelets of *M. javanicus* (Red Arrow); 2. *A. clavata*; 2a. Natural microhabitat of *A. clavata* on flooded pneumatophores of *A. marina*; 2b. Close view of Microhabitat; 2c. Feeding tunnels (TL) produced by *A. clavata*; 3. Dead twigs (Arrow) of *C. crista*; 3 a & b. Microhabitat selected by *Indoribates (I.) punctulatus*; 4. Dead barks of *D. trifoliata*; 4a. Adults of *Prototripoda (P.) trifoliatus* sp. nov.; 4b. Selected microhabitat of *P. (P.) trifoliatus* sp. nov. on dead barks of *C. crista*; 5. Morphological modifications in claws of different mangrove dwelling oribatid species; 5a. Toothed and hook like claw of *S. mangrovius*; 5b. Tridactylous claws of *P. (P.) trifoliatus*; 5c. monodactylous claws of *A. clavata*; d & e. monodactylous claws (Arrow) of *H. epimeratus* sp. nov.

PLATE 48

**Duration of Development of Life Stages of *H.epimeratus* gen.nov., sp. nov.
at $28\pm 2^{\circ}\text{C}$ and Relative Humidity $\text{RH} = 79\pm 2\%$ (in days)**

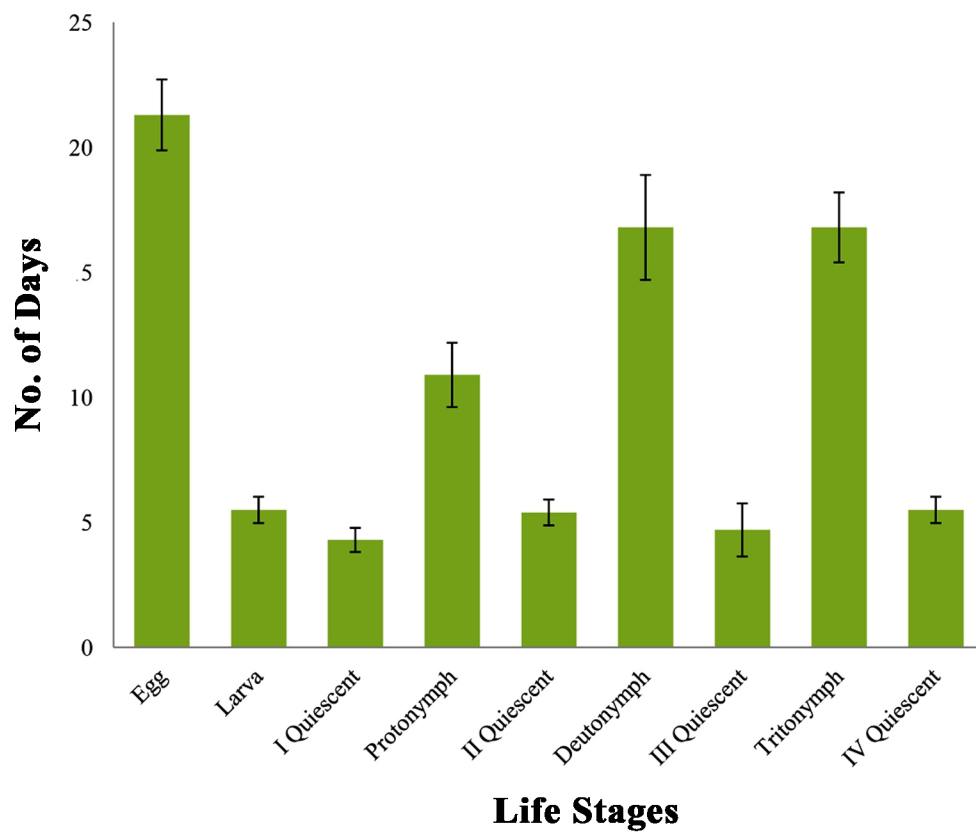


PLATE 49

Developmental Stages of *H. epimeratus* gen.nov. sp.nov.

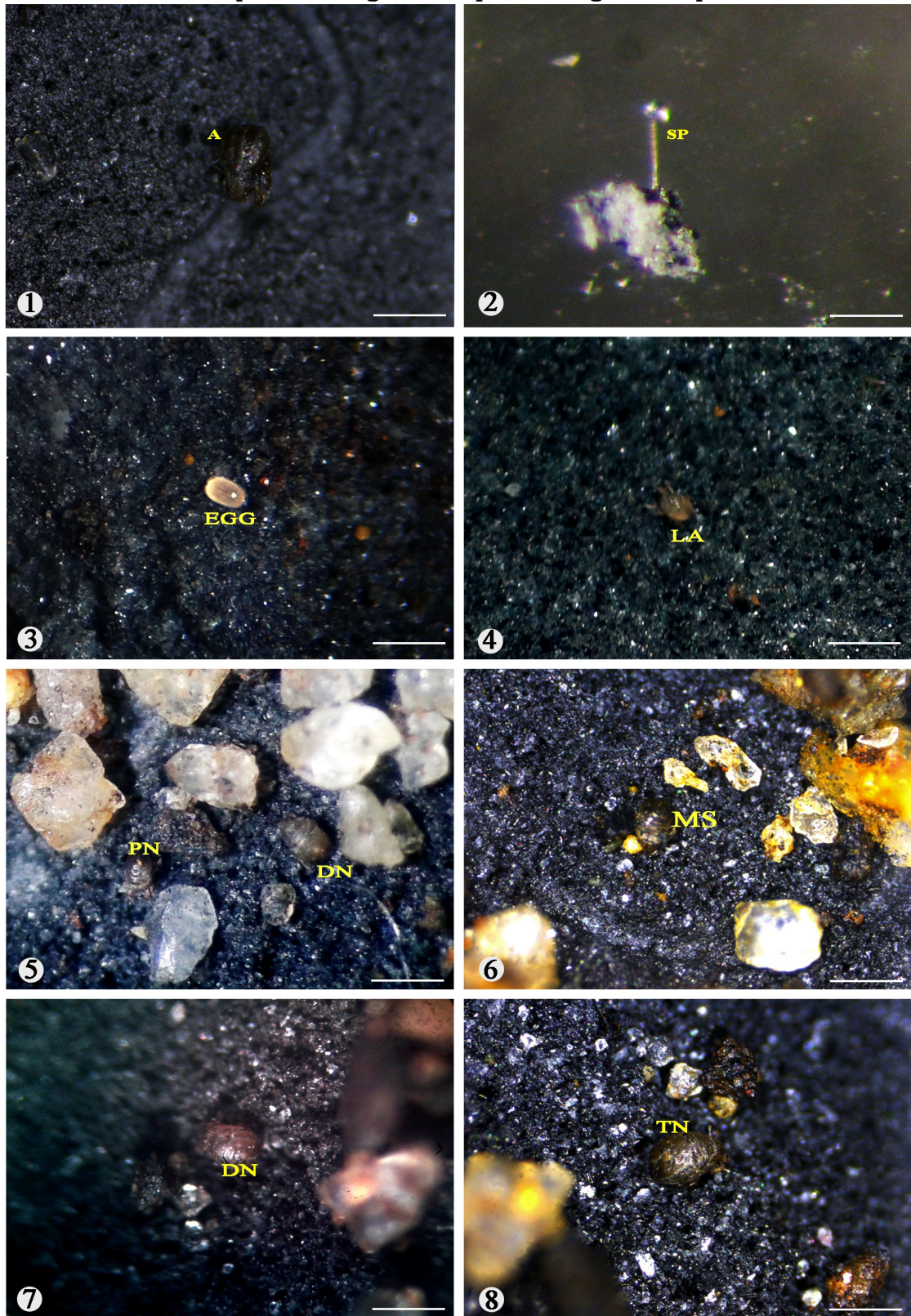


Fig.1. Adult (A) of *H. epimeratus* gen.nov.,sp.nov.; 2.Stalked Spermatophore (SP) of *H. epimeratus* sp.nov.; 3. Egg of *H. epimeratus* sp.nov.; 4.Larva of *H. epimeratus* sp.nov.; 5.Newly Moulted (PN) and-Deutonymph(DN);6.Moulting Skin of Quiescent Protonymph;7.Deutonymph;8.Quiescent Tritonymph. (Scale bar = 0.2mm)

PLATE 50

Morphological Features of Developmental Stages of *H. epimeratus* gen.nov.sp. nov.

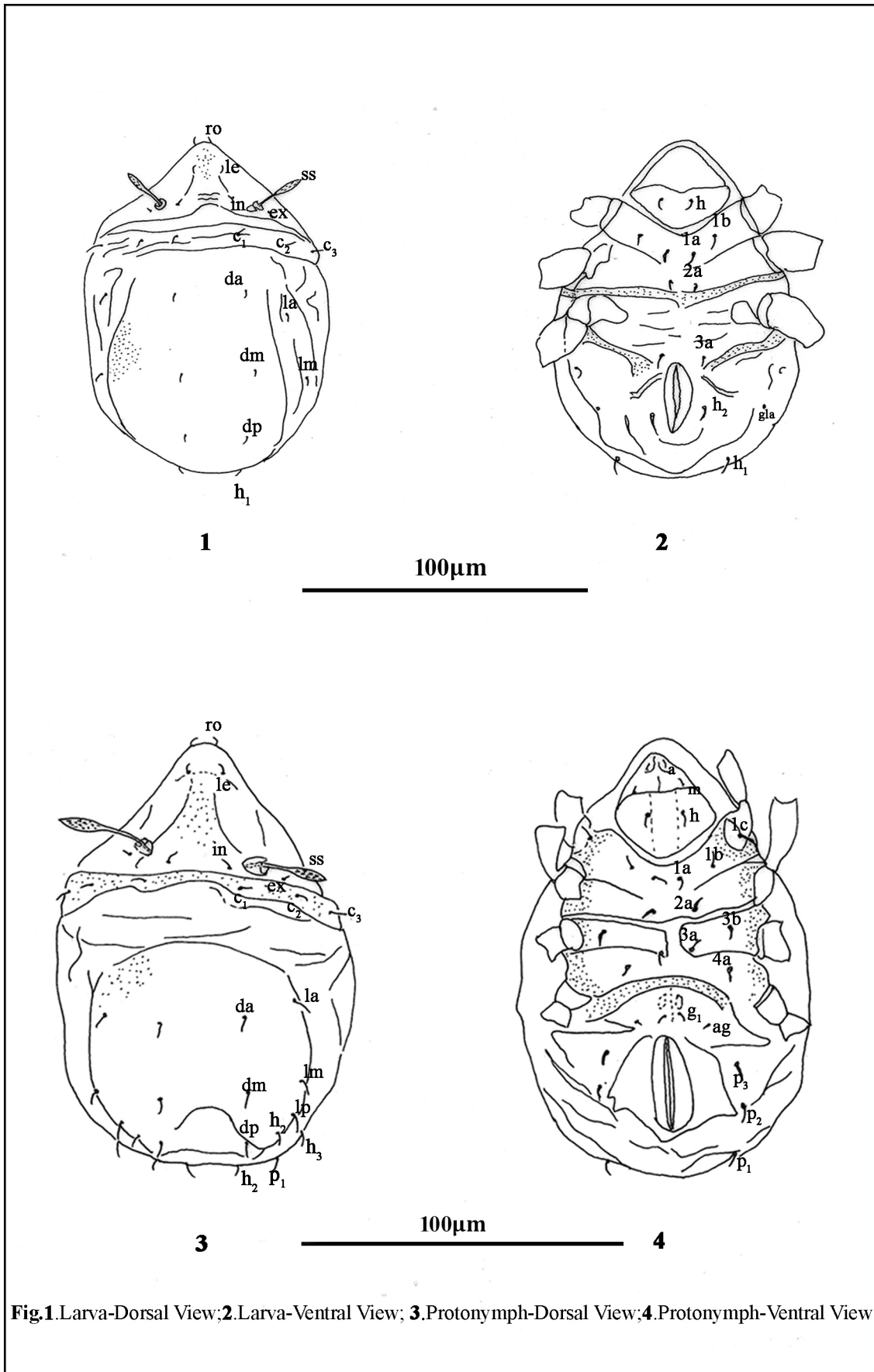


Fig.1.Larva-Dorsal View;2.Larva-Ventral View; 3.Protonymph-Dorsal View;4.Protonymph-Ventral View

PLATE 51

Morphological Features of Developmental Stages of *H. epimeratus* gen.nov.sp. nov.

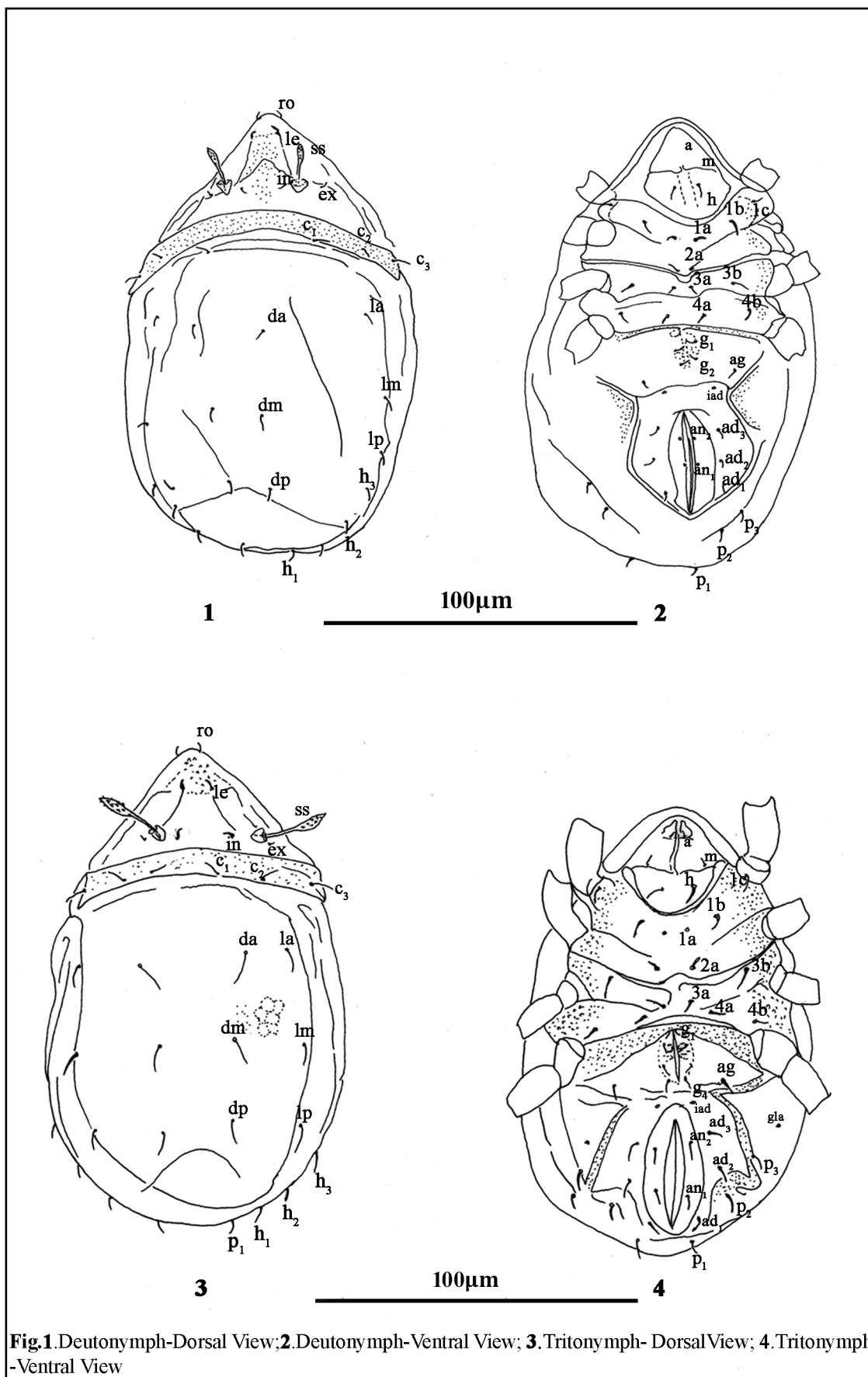


PLATE 52

Slide Mounted Photographs of Developmental Stages of *H.epimeratus* gen.nov.sp.nov.

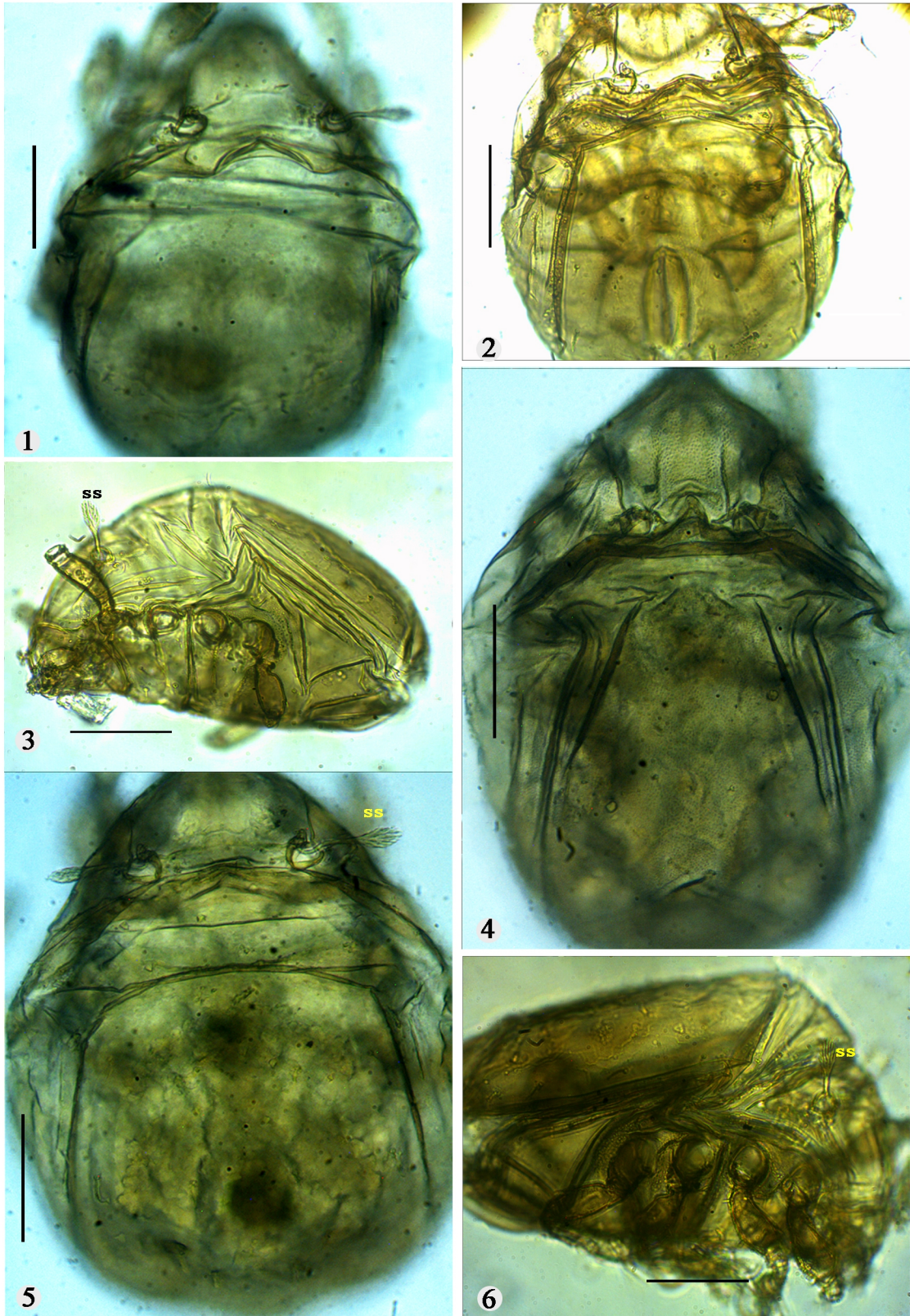


Fig.1.Larva-Dorsal View; 2.Protonymph-Dorsal View; 3. Protonymph- Lateral View; 4.Deutonymph-Dorsal View;5.Tritonymph- Dorsal View;6.Tritonymph- Lateral View(All images are sequentially layered from 5-7 images.(Scale bar =50 μ m).

PLATE 53

**Duration of Development of Life Stages of *A. clavata* Märkel, 1964
at $28\pm 2^{\circ}\text{C}$ and Relative Humidity $\text{RH} = 79\pm 2\%$ (in days)**

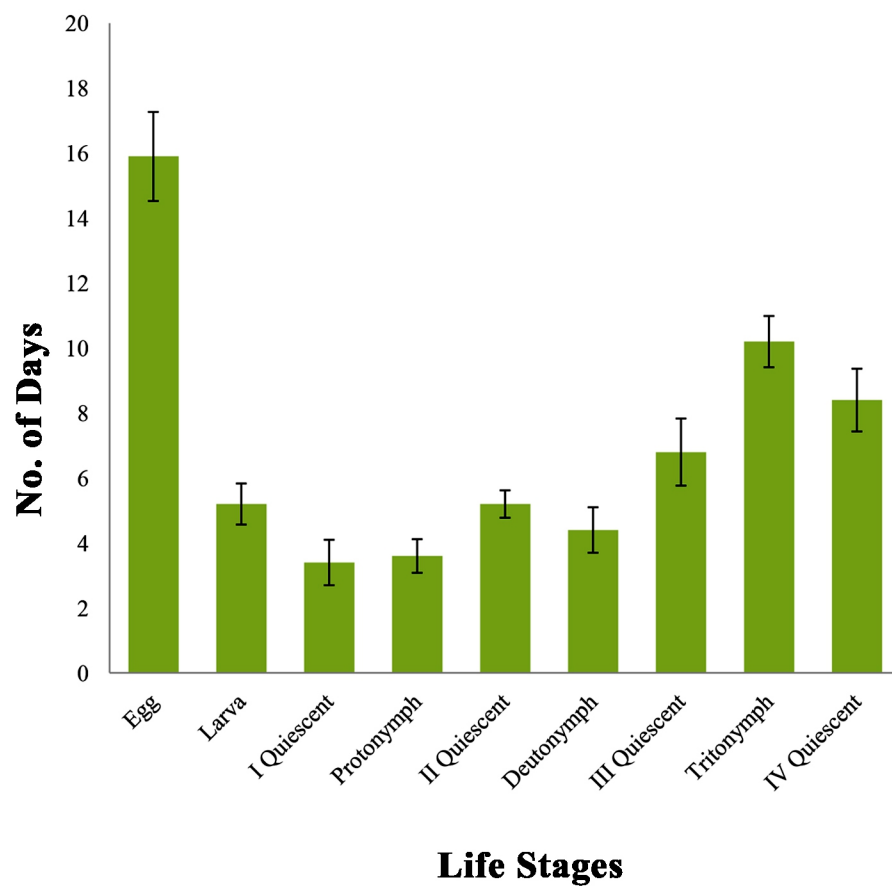
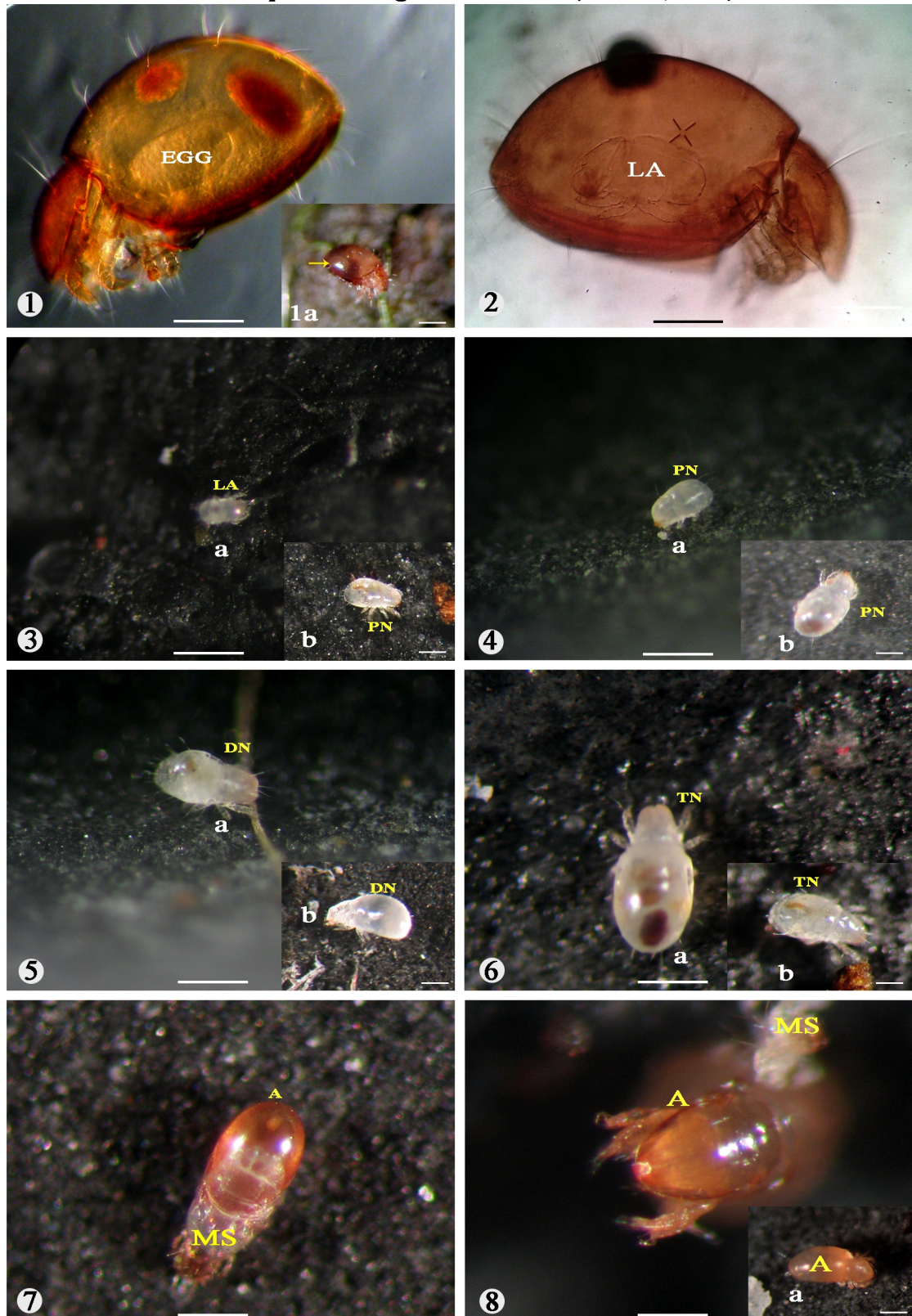


PLATE 54

Developmental stages of *A.clavata* (Märkel, 1964)



Figs.1&1a. Adult of *A.clavata* Showing Egg Inside the Body; 2. Adult of *A.clavata* with Fully Developed Larva (LA); 3.a.Newly Emerged Larva (LA) and b.Protonymph (PN);4.a.Protonymph;b.Quiescent Protonymph; 5.a.Deutonymph(DN) Feeding on Dead Filaments of *Microspora* sp.;b.Quiescent Deutonymph; 6.a.Tritonymph (TN);b.Quiescent Tritonymph; 7&8.Moulting of Quiescent Tritonymph to Adult (A) and Moulting Skin (MS) of Quiescent Tritonymph; 8.a.Newly emerged Adult(A)(Scale bar=1mm).

PLATE 55

Morphological Features of Developmental Stages of *A. clavata* (Märkel, 1964)

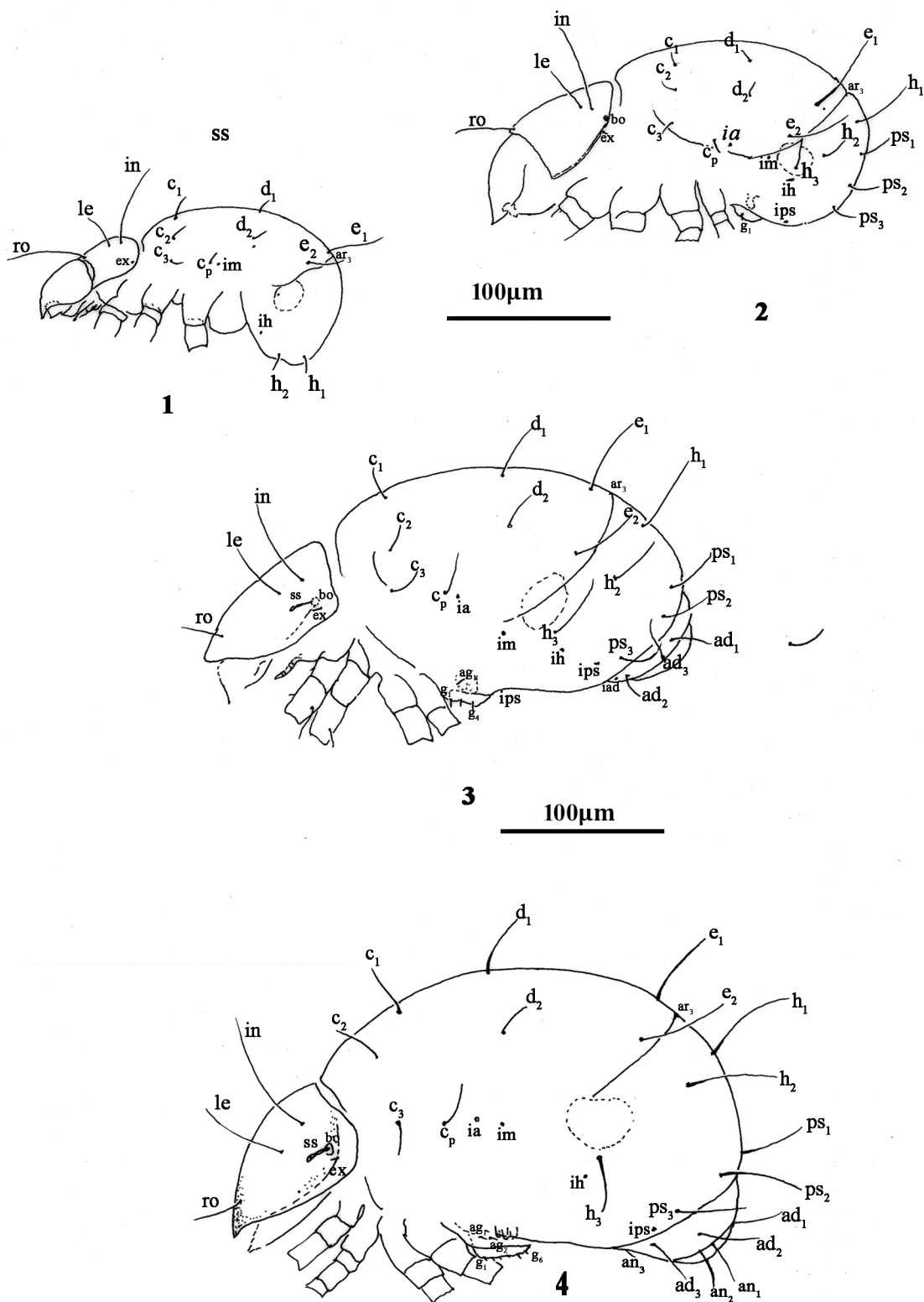


Fig. 1. Larva; 2. Protonymph ; 3. Deutonymph; 4. Tritonymph (Lateral View)

Table.1. Sites Surveyed

NO	STUDY SITES	LATITUDE AND LONGITUDE	DISTANCE from seashore (km)	DISTRICT
1	Brahmasampadam (BRSPM)	11° 7'35.46"N 75°52'9.09"E	4.4	MALAPPURAM
2	Olipramkadavu (OPKDV)-	11° 7'41.40"N 75°51'50.72"E	4.2	
3	Kadalundi-Vallikkunnu community reserve mangrove –I (KVCR-I)	11°7'37.51"N 75°49'54.64"E.	0.65	KOZHIKODE
4	Kadalundi-Vallikkunnu community reserve mangrove –II (KVCR-II):	11° 7'54.89"N 75°49'44.55"E	0.85	
5	Kottakkadavu (KTKDV)	11°8'15.99"N 75°50'28.26"E.	2.23	
6	Kallai (KLAI)	11°14'16.72"N 75°47'14.12"E.	1.42	
7	Mankavu (MNKV)	11°14'7.69"N 75°48'13.52"E	2.88	
8	Thalassery (TLSRY)	11°45'18.12"N 75°29'30.58"E.	2.2	KANNUR
9	Koduvalli (KDVLV)	11°45'59.30"N 75°28'42.06"E	0.29	
10	Valapattanam River (VLMRVR)	11°56'3.92"N 75°21'4.73"E.	6.3	
11	Dharmadam (DRMDM)	11°46'51.88"N 75°27'42.69"E.	0.84	
12	Ezhome (EZHM) -I	12° 1'38.28"N 75°17'0.72"E	5.64	
13	Ezhome (EZHM)- II	12° 1'33.55"N 75°16'34.64"E	5.84	
14	Pazhayangadi (PNGDY)	12° 1'36.90"N 75°16'24.05"E	5.55	KASARAGOD
15	Nileswaram (NLSRM)	12°15'58.03"N 75° 7'13.61"E	7.39	

Table.2. Major Types of Vegetation in the Mangrove Ecosystem Surveyed

NO	Species Name	Family	Habit	Common Name (English)	Local Name (Malayalam)	Type
1	<i>Acanthus ilicifolius</i> L.	Acanthaceae	Shrub	Sea Holly/ Holy mangrove	Chullikkandal	TM
2	<i>Aegiceras corniculatum</i> (L.) Blanco	Myrsinaceae	Shrub	Black mangrove/ River mangrove	Pookandal	TM
3	<i>Avicennia marina</i> (Forsk.) Vierh	Avicenniaceae	Tree	Grey mangrove/ White mangrove	Cheruppotti	TM
4	<i>Avicennia officinalis</i> L.	Avicenniaceae	Tree	Indian mangrove/ Grey mangrove	Uppotti	TM
5	<i>Bruguiera cylindrica</i> (L.)	Rhizophoraceae	Tree	Orange mangrove	Kuttikandal	TM
6	<i>Excoecaria agallocha</i> L.	Euphorbiaceae	Tree	Milky mangrove /blind-your- mangrove/river poison tree	Kannampotti	TM
7	<i>Rhizophora apiculata</i> Blume.	Rhizophoraceae	Tree	Red mangroves	Kayakandal	TM
8	<i>Rhizophora mucronata</i> Blume.	Rhizophoraceae	Tree	Red mangroves	Panachikandal	TM
9	<i>Acrostichum areum</i> L	Pteridaceae	Fern	Golden leather fern/ Swamp fern/Mangrove fern	Machintholu	MA
10	<i>Caesalpinia crista</i> L.	Caesalpiniaceae	Climber	Fever nut	Attuparanda /Kakkamullu/ Manjapoovali	MA
11	<i>Clerodendrum inerme</i> (L.) Gaertn	Verbenaceae	Shrub	Wild Jasmine/Sorcerers bush	Puzhamulla/Sankukuppi	MA
12	<i>Derris trifoliata</i> Lour	Fabaceae	Climber	-	Ponnumvalli/ Kammattivalli	MA
13	<i>Ipomoea pes-caprae</i> (L.) R.Br.	Convolvulaceae	Herb	Goat's foot creeper	Kuthirakulamban/Adambu	MA
14	<i>Ipomoea violacea</i> L.	Convolvulaceae	Climber	Heavenly Blue Morning Glory	-	MA
15	<i>Morinda citrifolia</i> L.	Rubiaceae	Tree	Great Morinda/ Indian Mulberry	Cherumanjanathi	MA
16	<i>Pongamia pinnata</i> (L.) Pierre	Fabaceae	Tree	Indian beach tree/ Pongam oil tree	Ungu /Minnari	MA
17	<i>Alternanthera bettzickiana</i> (Rogell)	Amaranthaceae	Herb	-	-	-
18	<i>Premna serratifolia</i> L.	Verbenaceae	Shrub	Head ache tree	Munja / Kozhichedi	MA
19	<i>Lantana camara</i> L.	Verbenaceae	Shrub	Lantana/Wild Sage	Arippoochedi	-
20	<i>Ludwigia hyssopifolia</i> (G.Don) Exell	Scrophulariaceae	-	-	-	-
21	<i>Fimbristylis ferruginea</i> (L.) Vahl	Cyperaceae	Herb	Common Finger Rush	Puzha Potta	MA
22	<i>Mariscus javanicus</i> Houtt.) Merr & Metcalf.	Poaceae/ Cyperaceae	Herb	Sharp Cyperus	Vaaleera	MA
23	<i>Pennisetum pedicellatum</i> Trin.	Poaceae	Herb	Kyasuva grass	Poochavalanpullu/ Oolappullu	-
24	<i>Saccharum arundinaceum</i> Retz.	Poaceae/Graminae	Herb	Devil Sugar Cane	Munjappullu/ Meghappullu	MA
25	<i>Wedelia chinensis</i> (Osbeck) Merr.	Asteraceae/ Compositae	Herb	-	Aswagandhi/ Manjakkanjunni -	MA

TM-True Mangrove; MA-Mangrove Associate

Table. 3. Dominant Floral Composition of the Study Site

Sl. No	STUDY SITES	MANGROVE PLANT SPECIES
1	Brahmasampadam (BRSPM)	<i>Avicennia marina</i> , <i>A. officinalis</i> , <i>Acanthus ilicifolius</i> , <i>Acrostichum aeurium</i> , <i>Caesalpinia crista</i>
2	Olipramkadavu (OPKDV)	<i>A. ilicifolus</i> <i>A.officinalis</i> and <i>Pongamia pinnata</i> and <i>Acrostichum.aeurium</i>
3	Kadalundi-Vallikkunnu Community Reserve Mangrove –I (KVCR-I)	<i>A.ilicifolius</i> , <i>A.marina</i> , <i>A. officinalis</i> , <i>Rhizophora mucronata</i> , <i>Clerodendrum inerme</i> <i>C. crista</i> , <i>Derris trifoliata</i> , <i>Ipomea pes-caprae</i> , <i>Mariscus javanicus</i> and <i>Pennisetum pedicellatum</i> <i>Excoecaria agallocha</i> .
4	Kadalundi-Vallikkunnu Community Reserve Mangrove –II (KVCR-II)	<i>A.marina</i> , <i>A.ilicifolius</i> <i>M. javanicus</i> and <i>D. trifoliata</i>
5	Kottakkadavu (KTKDV)	<i>A.officinalis</i> , <i>A.ilicifolius</i> , <i>E. agallocha</i>
6	Kallai (KLAI)	<i>A.marina</i> , <i>A.ilicifolus</i>
7	Mankavu (MNKV)	<i>A.marina</i> , <i>A.ilicifolus</i> and <i>A. ilicifolius</i>
8	Thalassery (TLSRY)	<i>A.marina</i> , <i>D. trifoliata</i> , <i>R. mucronata</i> , <i>A. ilicifolius</i> and <i>C.crista</i>
9	Koduvalli (KDPLY)	<i>A.marina</i> , <i>A.ilicifolus</i> and <i>R. mucronata</i>
10	Valapattanam River (VLMRVR)	<i>A.ilicifolus</i> , <i>A.officinalis</i> , <i>A.marina</i> <i>Aegiceras corniculatum</i>
11	Dharmadam (DRMDM)	<i>Rhizophora apiculata</i> , <i>A.marina</i> , <i>A.ilicifolus</i> and <i>D. trifoliata</i>
12	Ezhome (EZHM) -I	<i>A.officinalis</i> . <i>Bruguiera cylindrica</i> <i>E. agallocha</i> , <i>A.corniculatum</i> , <i>M.javanicus</i>
13	Ezhome (EZHM)- II	<i>A.officinalis</i> , <i>E. agallocha</i> , <i>D. trifoliata</i> <i>A.corniculatum</i> , <i>C.inerme</i>
14	Pazhayangadi (PNGDY)	<i>E. agallocha</i> , <i>A.officinalis</i> , <i>A.officinalis</i> , <i>C.crista</i>
15	Nileswaram (NLSRM)	<i>A.officinalis</i> , <i>A.ilicifolius</i>

Table4. Systematic position and distribution of oribatid mites recorded from various mangrove ecosystems of North Kerala, India. Based on oribatid mite catalogue by Subias (2004) actualized and updated in 2015

SL NO	SUB ORDER	SUPER FAMILY	FAMILY	GENUS	SUB GENUS	SPECIES	SPECIES NUMBER STATUS	WORLD DISTRIBUTION	SPECIES STATUS
1	ENARTHRONOTA Grandjean 1947	Cosmochthonioidea Grandjean, 1947	Cosmochthoniidae Grandjean, 1947	<i>Cosmochthonius</i> Berlese, 1910	<i>Cosmochthonius</i> (<i>Cosmochthonius</i>) Berlese, 1910	<i>Cosmochthonius</i> (<i>C.</i>) <i>reticulatus</i> Grandjean, 1947.	35sp &3ssp.	Mediterranean and Brazil	Reported Julie <i>et al.</i> 2013
		Lohmannioidea Berlese 1916	Lohmanniidae Berlese, 1916	<i>Annectacarus</i> Grandjean, 1950		<i>Annectacarus unilateralis</i> Hammer, 1973	17sp.	Tropical:Polinesia(I.Tonga) Java and Galapagos	New record
				<i>Haplacar</i> wallwork, 1962		<i>Haplacar</i> <i>aureus</i> sp. nov.	11 spp & 1 ssp	Pantropical	New record / New to science
				<i>Heptacar</i> Piff, 1963		<i>Heptacar</i> <i>hirsutus</i> Wallwork, 1964	10spp.	Ethiopia(Chad)& Oriental (India: Kerala)	New record
				<i>Javacar</i> Balogh, 1961	<i>Javacar</i> (<i>Javacar</i>) Balogh , 1961	<i>Javacar</i> (<i>J.</i>) <i>porosus</i> Hammer, 1979	10spp.	Pan tropical Except Australia	New record
2	EUPTYCTIMA Grandjean, 1967	Euphthiraroidea Jacot, 1930	Euphthiracaridae Jacot, 1930	<i>Acrotrit</i> Jacot, 1923		<i>Acrotrit</i> <i>clavata</i> (Märkel, 1964)	51spp.2ssp	Neotropical, Ethiopia & Oriental(India: Kerala)	New record Syamjith& Ramani, 2013
		Phthiraroidea Perty, 1841	Phthiracaridae Perty, 1841	<i>Hoplophorella</i> Berlese, 1923	<i>Hoplophorella</i> (<i>Hoplophorella</i>) Berlese, 1923	<i>Hoplophorella</i> (<i>H.</i>) <i>vitrina</i> (Berlese, 1913)	106 spp. 90ssp.	Pantropical &Subtropical	New record
3	HOLOSOMATA Grandjean, 1969	Crotonioidea Thorell, 1876	Trhypochthoniidae Willmann, 1931	<i>Afronthrus</i> Wallwork, 1961		<i>Afronthrus arboreus</i> Ramani &Haq, 1992	2spp	Pantropical & Oriental (India: Kerala)	New record
				<i>Archezogetes</i> Grandjean, 1931		<i>Archezogetes longisetosus</i> Aoki, 1965	2spp 1ssp	Pantropical	New record
4	PYCNONOTICAE Grandjean, 1954	Carabodoidea	Carabodidae Koch, 1837	<i>Carabodes</i> Koch, 1837	<i>Carabodes</i> (<i>Klapperiches</i>) Mahunka, 1979	<i>Carabodes</i> (<i>K.</i>) <i>penicillus</i> Mahunka, 1979	137spp.3ss pp--45spp. 2sspp	Cosmopolitan Except Antartica	New record
		Ameronothroidea Willmann, 1931	Selenoribatidae Schuster, 1963	<i>Selenoribates</i> Strenzke, 1961		<i>Selenoribates mangrovius</i> sp.nov.	6sp	Pantropical/except Australia & Palearctic Meridional	New record/New to science
			Fortuyniidae Schuster, 1963	<i>*Holocarinozetes</i> Gen. nov.		<i>Holocarinozetes</i> <i>epimeratus</i> sp.nov.	1sp	Oriental Kerala, India.	New record/New to science

Table.4.cont.....

SL NO	SUB ORDER	SUPER FAMILY	FAMILY	GENUS	SUB GENUS	SPECIES	NO OF SPECIES	WORLD DISTRIBUTION	SPECIES STATUS
5	PORONOTICAE Grandjean, 1954	Limnozetoidea Thor, 1937	Austrachipteriidae Luxton, 1985	<i>Lamellobates</i> Hammer, 1958	<i>Lamellobates</i> (<i>Lamellobates</i>) Berlese, 1910	<i>Lamellobates</i> (<i>L.</i>) <i>molecula</i> Grandjean, 1947.	11sp. & 1sp 8ssp	Pantropical & Subtropical	New record
					<i>Lamellobates</i> (<i>Paralamellobates</i>) Bhaduri & Raychaudhuri, 1968	<i>Lamellobates</i> (<i>P.</i>) <i>bengalensis</i> Bhaduri & Raychaudhuri, 1968	3spp	Pantropical & Palearctic Meridional	New record
		Oripodoidea Jacot, 1925	Oribatulidae Thor, 1925	<i>Phauloppia</i> Berlese, 1908		<i>Phauloppia kadalundiensis</i> sp.nov	25 spp	Semicosmopolitan (Holártica, Australiana y Neotropical).	New record/New to science
			Hemileiidae J&P. Balogh, 1984	<i>Siculobata</i> Grandjean, 1953	<i>Siculobata</i> (<i>Siculobata</i>) Grandjean, 1953	<i>Siculobata</i> (<i>S.</i>) <i>malabarica</i> Ramani & Haq, 1998	7spp & 4sp&1ssp	Cosmopolitan	New record
			Scheloriobatidae Grandjean, 1933	<i>Scheloribates</i> Berlese, 1908	<i>Scheloribates</i> (<i>Scheloribates</i>) Berlese, 1908	<i>Scheloribates</i> (<i>S.</i>) <i>praeincisus</i> <i>interruptus</i> (Berlese, 1908)	221spp, (210ssp)19ssp	Cosmopolitan /Oriental/ Pacific /Neotropical.	Reported Julie <i>et al.</i> 2013
			Oripodidae Jacot, 1925	<i>Protoripoda</i> Balogh, 1970	<i>Protoripoda</i> (<i>Protoripoda</i>) Balogh, 1970	<i>Protoripoda</i> (<i>P.</i>) <i>trifoliatius</i> sp.nov.	11spp &7ssp	Pantropical (excepto Neotropical) &Palearctica meridional.	New record/New to science
			Protoribatidae J. y P. Balogh, 1984	<i>Protoribates</i> J. & P. Balogh, 1984	<i>Protoribates</i> (<i>Protoribates</i>) Berlese, 1908	<i>Protoribates</i> (<i>P.</i>) <i>capucinus</i> Berlese, 1908	78spp 51spp 3ssp	Cosmopolitan Except Antartica.	New record
			Haplozetidae Grandjean, 1936	<i>Indoribates</i> Jacot, 1929	<i>Indoribates</i> (<i>Indoribates</i>) Jacot, 1929	<i>Indoribates</i> (<i>I.</i>) <i>punctulatus</i> (Sellnick, 1925)	33 spp 11spp. 1ssp	Cosmopolitan except Antartica	New record
				<i>Trachyoribates</i> Berlese, 1908	<i>Trachyoribates</i> (<i>Rostrozetes</i>) Sellnick, 1925	<i>Trachyoribates</i> (<i>R.</i>) <i>ovulum ovulum</i> Berlese, 1908	31 spp 29spp 2ssp	Pantropical and Subtropical	Reported Julie <i>et al.</i> 2013
				<i>Trachyoribates</i> Berlese, 1908	<i>Trachyoribates</i> (<i>Rostrozetes</i>) Sellnick, 1925	<i>Trachyoribates</i> (<i>R.</i>) <i>nortonii</i> sp.nov.			New record
		Galumnoidea Jacot, 1925	Galumnidae Jacot, 1925	<i>Galumna</i> Heyden, 1826	<i>Galumna</i> (<i>Galumna</i>) Heyden, 1826	<i>Galumna</i> (<i>Galumna</i>) <i>paragibbula</i> Weigmann, 2011	183spp 165	Cosmopolitan	New record

Table. 5. Site wise Distribution of Oribatid mites Recorded from Various Mangrove Ecosystems of North Kerala, India.

SUPERFAMILY	FAMILY	SPECIES	SAMPLING LOCALITIES															
			MPM		KKD					KNR							KSD	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			BRSPM	OPKDV	KVCR-I	KVCR-II	KTKDV	KLAI	MNKV	TLSRY	KDVLV	VLMRVR	DRMDM	EZHM-I	EZHM-II	PNGDY	NLSRM	
Cosmochthonioidea Grandjean, 1947	Cosmochthoniidae Grandjean, 1947	1	<i>Cosmochthonius(C.) reticulatus</i> Grandjean, 1947	-	-	-	+	-	-	-	-	-	-	-	-	-	+	
Lohmannioidea Berlese 1916	Lohmanniidae Berlese, 1916	2	<i>Annectacarus unilateralis</i> Hammer, 1973	-	-	-	+	-	+	+	+	+	-	-	-	-	-	
		3	<i>Haplacarus aureus</i> sp.nov.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	
		4	<i>Heptacarus hirsutus</i> Wallwork, 1964	+	-	+	-	-	-	-	-	+	-	+	-	-	-	-
		5	<i>Javacarus (J.) porosus</i> Hammer, 1979	-	-	-	-	-	+	+	-	-	-	+	-	+	-	-
Euphthiracaroida Jacot, 1930	Euphthiracaridae Jacot, 1930	6	<i>Acrotritia clavata</i> (Märkel, 1964)	-	-	+	-	-	-	-	+	-	-	-	-	-	+	
Phthiracaroida Perty, 1841	Phthiracaridae Perty, 1841	7	<i>Hoplophorella (H.) vitrina</i> (Berlese, 1913)	-	+	-	+	+	-	-	+	-	-	-	-	+	-	
Crotonioidea Thorell, 1876	Trhypochthoniidae Willmann, 1931	8	<i>Afronthrus arboreus</i> Ramani &Haq, 1992	-	-	+	-	-	-	-	-	-	-	-	-	-	-	
		9	<i>Archegozetes longisetosus</i> Aoki, 1965	-	-	-	-	-	-	-	+	-	-	+	-	-	+	+
Carabodoidea	Carabodidae Koch, 1837	10	<i>Carabodes (K.) penicillus</i> Mahunka, 1979	-	-	+	-	-	-	-	-	-	-	-	+	-	-	
Ameronothroidea Willmann, 1931	Selenoribatidae Schuster, 1963	11	<i>Selenoribates mangrovius</i> sp.nov.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	
	Fortuyniidae Schuster, 1963	12	<i>Holocarinozetes epimeratus</i> sp.nov.	-	-	-	+	-	-	-	-	-	-	-	-	-	-	

Sites: 1. Brahmasampadam (BRSPM); 2. Olipramkadavu (OPKDV); 3. Kadalundi-Vallikkunnu community reserve mangrove –I (KVCR-I); 4. Kadalundi-Vallikkunnu community reserve mangrove –II (KVCR-II); 5. Kottakkadavu (KTKDV); 6. Kallai (KLAI); 7. Mankavu (MNKV); 8. Thalassery (TLSRY); 9. Koduvalli (KDVLV); 10. Valapattan River Bank (VLMRVR); 11. Dharmadam (DRMDM); 12. Ezhome (EZHM) –I; 13. Ezhome (EZHM) –II; 14. Pazhayangadi (PNGDY); 15. Nileswarem (NLSRM)

Table. 5.Conti.....

SUPERFAMILY	FAMILY	SPECIES	SAMPLING LOCALITIES														
			MPM		KKD					KNR							KSD
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			BRSPM	OPKDV	KVCR-I	KVCR-II	KTKDV	KLAI	MNKV	TLsRY	KDVL Y	VLMRVR	DRMDM	EZHM-I	EZHM-II	PNGDY	NLSRM
Limnozetoidea Thor, 1937	Austrachipteriidae Luxton, 1985	13	<i>Lamellobates(L.)molecula</i> Grandjean,1947	+	-	+	-	-	-	-	-	+	-	-	-	-	+
		14	<i>Lamellobates (P.) bengalensis</i> Bhaduri & Raychaudhuri, 1968	+	+	-	-	-	-	-	-	-	-	-	-	+	-
Oripodoidea Jacot, 1925	Oribatulidae Thor, 1925	15	<i>Phauloppia kadalundiensis</i> sp.nov	-	-	-	+	-	-	-	-	-	-	-	-	-	-
	Hemileiidae J&P. Balogh, 1984	16	<i>Siculobata (S.) malabarica</i> Ramani & Haq, 1998	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	Scheloribatidae Grandjean , 1933	17	<i>Scheloribates (S.) praeincisus</i> <i>interruptus</i> (Berlese, 1908)	-	+	-	+	-	-	+	-	-	-	+	-	+	-
	Oripodidae Jacot, 1925	18	<i>Protoripoda (P.) trifolius</i> sp.nov.	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	Protoribatidae J. & P. Balogh, 1984	19	<i>Protoribates (P.) capucinus</i> Berlese, 1908	+	-	-	-	-	-	-	-	+	-	-	+	-	-
	Haplozetidae Grandjean, 1936	20	<i>Indoribates (I.) punctulatus</i> (Sellnick, 1925)	+	-	-	+	+	+	-	+	-	+	-	+	-	+
		21	<i>Trachyoribates</i> <i>(R.) ovulum ovulum</i> Berlese, 1908	-	+	-	-	-	+	-	-	+	-	-	+	-	-
		22	<i>Trachyoribates (R.) nortonii</i> sp.nov.	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Galumnoidea Jacot, 1925	Galumnidae Jacot, 1925	23	<i>Galumna (G.) paragibbula</i> Weigmann, 201	-	-	-	+	-	-	-	+	-	-	+	-	-	-

Table.6. Quantitative Difference in Nitrogen, Phosphorous and Potassium Levels in mangrove soil samples owing to oribatid mite presence

Parameters	Control	Treated
Nitrogen	2.54 ± 0.35	4.384 ± 0.496*
Phosphorus	22.224 ± 1.76	35.25 ± 2.78*
Potassium(K)	4.454 ± 0.665	11.218 ± 0.606*

Data were analyzed using statistical package and expressed as Mean ± Standard Deviation (SD). Two-tailed unpaired t-test were done and the values are set significant at P<0.05 and asterisks (*) denotes significant against the control group.

Table 7: Duration of Development of Life Stages of *Holocarinozetes epimeratus* gen. nov.sp. nov. at 28±2°C, RH=79±2 (in days)

Sl No	Egg	Larva	I Quiescent	Protonymph	II Quiscent	Deutonymph	III Quiescent	Tritonymph	IV Quiescent	Total
1	22	6	5	13	6	19	7	19	5	102
2	23	6	4	12	5	19	5	18	5	97
3	20	5	4	11	6	17	4	16	5	88
4	20	5	4	11	5	17	4	16	6	88
5	23	6	4	11	6	18	5	18	5	96
6	20	5	4	11	6	17	4	17	6	90
7	20	5	4	9	5	14	4	15	6	82
8	20	6	4	9	5	14	4	15	6	83
9	22	5	5	10	5	14	4	16	6	87
10	23	6	5	12	5	19	6	18	5	99
Range	20 - 23	5 - 6	4 - 5	10 - 13	5 - 6	14 - 19	4 - 7	15 - 19	5 - 6	82 - 102

Table.8: Appearance of Genital Setae at Different Stages of Development of *H.epimeratus* gen.nov.sp. nov.

Stage	Genital setae	Total number of genital setae	Setae appeared anew
Larva	-	-	-
Protonymph	g_1	1	1
Deutonymph	g_1, g_2	2	1
Tritonymph	g_1, g_2, g_3, g_4	4	2
Adult	g_1, g_2, g_3, g_4	4	-

Table. 9: Appearance of Adanal and Anal Setae at Different Stages of Development of *H.epimeratus* gen.nov. sp. nov.

Stage	Adanal segment			Anal segment		
	Setae	Number	Setae appeared anew	Setae	Number	Setae appeared anew
Larva	-	-	-	-	-	-
Protonymph	-	-	-	-	-	-
Deutonymph	ad_1, ad_2, ad_3	3	3	an_1, an_2	2	2
Tritonymph	ad_1, ad_2, ad_3	3	-	an_1, an_2	2	-
Adult	ad_1, ad_2, ad_3	3	-	an_1, an_2	2	-

Table. 10. Appearance of Epimeral Setae at Different Stages of Development of *H. epimeratus* gen.nov sp. nov

Stage	Epimere				Total number of setae	Setae appeared anew	Epimeral setal formula
	I	II	III	IV			
Larva	1a, 1b	2a	3a	-	4	4	2-1-1
Protonymph	1a, 1b, 1c	2a	3a, 3b	4a	7	3	3-1-2-1
Deutonymph	1a, 1b, 1c	2a	3a, 3b	4a,4b	8	1	3-1-2-2
Tritonymph	1a, 1b, 1c	2a	3a, 3b	4a,4b	8	-	3-1-2-2
Adult	1a, 1b, 1c	2a	3a, 3b	4a,4b	8	-	3-1-2-2

Table.11: Appearance of Notogastral Setae at Different Stages of Development of *H. epimeratus* gen.nov.sp. nov.

Stage	Rows					Total number of setae	Setae appeared anew
	First	Second	Third	Fourth	Fifth		
Larva	c ₁ , c ₂ , c ₃	da, dm, dp	la, im, lp	h ₁ , h ₂	-	11	11
Protonymph	c ₁ , c ₂ , c ₃	da, dm, dp	la, im, lp	h ₁ , h ₂ , h ₃	p ₁ , p ₂ , p ₃	15	4
Deutonymph	c ₁ , c ₂ , c ₃	da, dm, dp	la, im, lp	h ₁ , h ₂ , h ₃	p ₁ , p ₂ , p ₃	15	-
Tritonymph	c ₁ , c ₂ , c ₃	da, dm, dp	la, im, lp	h ₁ , h ₂ , h ₃	p ₁ , p ₂ , p ₃	15	-
Adult	c ₁ , c ₂ , c ₃	da, dm, dp	la, im, lp	h ₁ , h ₂ , h ₃	p ₁ , p ₂ , p ₃	15	-

Table.12.Diagnostic features of Life Stages of *H.epimeratus* gen.nov.sp. nov.

Stages Features	Larva	Protonymph	Deutonymph	Tritonymph	Adult
Nature of Sensillus	<i>Clavate/ head with small spines</i>	<i>Clavate with fine barbed head</i>	<i>Clavate, spinose apically</i>	<i>Clavate, spinose apically</i>	<i>Clavate, spinose apically</i>
No of notogastral setae	<i>11pairs</i>	<i>15 pairs</i>	<i>15 pairs</i>	<i>15 pairs</i>	<i>15 pairs</i>
Epimeral setal formula	<i>2-1-1</i>	<i>3-1-2-1</i>	<i>3-1-2-2</i>	<i>3-1-2-2</i>	<i>3-1-2-2</i>
Number of genital setae	<i>0</i>	<i>1 pair</i>	<i>2 pairs</i>	<i>4 pairs</i>	<i>4 pairs</i>
Number of genital suckers	<i>0</i>	<i>1 pair</i>	<i>2 pairs</i>	<i>3 pairs</i>	<i>3 pairs</i>
Number of adanal setae	<i>0</i>	<i>0</i>	<i>3 pairs</i>	<i>3 pairs</i>	<i>3 pairs</i>
Number of anal setae	<i>0</i>	<i>0</i>	<i>2 pairs</i>	<i>2 pairs</i>	<i>2 pairs</i>
Legs	<i>3 pairs Monodactylous</i>	<i>4 pairs Monodactylous</i>	<i>4 pairs Monodactylous</i>	<i>4 pairs Monodactylous</i>	<i>4 pairs Monodactylous</i>
Length/Width (Average)	<i>126/88µm</i>	<i>147/98 µm</i>	<i>180/110 µm</i>	<i>213/130 µm</i>	<i>300/195 µm</i>

Table.13: Duration of Development of Life Stages of *Acrotritia clavata* (Märkel, 1964) at 28±2°C, RH = 79 ± 2% (in days)

Sl No	Egg	Larva	I Quiescent	Protonymph	II Quiescent	Deutonymph	III Quiescent	Tritonymph	IV Quiescent	Total
1	14	5	3	4	5	5	6	11	8	61
2	17	6	3	3	5	3	6	10	8	61
3	14	4	3	4	5	5	8	11	9	63
4	18	6	5	4	6	5	9	10	9	72
5	17	6	3	4	5	5	7	9	7	63
6	16	5	4	3	5	4	6	10	9	62
7	16	5	4	3	5	5	6	9	9	62
8	17	5	3	3	6	4	6	10	8	62
9	15	5	3	4	5	4	7	11	7	61
10	15	5	3	4	5	4	7	11	10	64
Range	14 -18	5 - 6	3- 5	3 - 4	5 – 6	3 - 5	6 - 9	10 - 11	7 - 9	61 - 72

Table.14: Appearance of Genital Setae at Different Stages of Development of *A. clavata* (Märkel, 1964)

Stage	Genital setae	Total number of genital setae	Setae appeared anew
Larva	-	-	-
Protonymph	g_1	1	1
Deutonymph	g_1, g_2, g_3, g_4	4	3
Tritonymph	$g_1, g_2, g_3, g_4, g_5, g_6$	6	2
Adult	$g_1, g_2, g_3, g_4, g_5, g_6$	6	-

Table. 15: Appearance of Adanal and Anal Setae at Different Stages of Development of *A. clavata* (Märkel, 1964)

Stage	Adanal segment			Anal segment		
	Setae	Number	Setae appeared anew	Setae	Number	Setae appeared anew
Larva	-	-	-	-	-	-
Protonymph		-	-	-	-	-
Deutonymph	ad_1, ad_2, ad_3	3	3	-	-	-
Tritonymph	ad_1, ad_2, ad_3	3	3	an_1, an_2, an_3	3	3
Adult	ad_1, ad_2, ad_3	3	3	an_1, an_2, an_3	3	-

Table. 16. Appearance of Epimeral Setae at Different Stages of Development of *A. clavata* (Märkel, 1964)

Stage	Epimere				Total number of setae	Setae appeared anew	Epimeral setal formula
	I	II	III	IV			
Larva	1a, 1b, 1c	2a	3a, 3b	-	6	6	3-1-2
Protonymph	1a, 1b, 1c	2a	3a, 3b	4a	7	1	3-1-2-1
Deutonymph	1a, 1b, 1c	2a	3a, 3b, 3c	4a, 4b	9	2	3-1-3-2
Tritonymph	1a, 1b, 1c	2a	3a, 3b, 3c	4a, 4b, 4c	10	1	3-1-3-3
Adult	1a, 1b, 1c	2a	3a, 3b	4a, 4b	10	-	3-1-3-3

Table.17: Appearance of Notogastral Setae at Different Stages of Development of *A. clavata* (Märkel, 1964)

Stage	Rows						Total number of setae	Setae appeared anew
	First	Second	Third	Fourth	Fifth	Sixth		
Larva	c_1, c_2, c_3	c_p	$d_1, d_2,$	e_1, e_2	h_1, h_2	-	10	10
Protonymph	c_1, c_2, c_3	c_p	$d_1, d_2,$	e_1, e_2	h_1, h_2, h_3	ps_1, ps_2, ps_3	14	4
Deutonymph	c_1, c_2, c_3	c_p	$d_1, d_2,$	e_1, e_2	h_1, h_2, h_3	ps_1, ps_2, ps_3	14	-
Tritonymph	c_1, c_2, c_3	c_p	$d_1, d_2,$	e_1, e_2	h_1, h_2, h_3	ps_1, ps_2, ps_3	14	-
Adult	c_1, c_2, c_3	c_p	$d_1, d_2,$	e_1, e_2	h_1, h_2, h_3	ps_1, ps_2, ps_3	14	-

Table.18.Diagnostic features of Life Stages of *A.clavata* (Märkel, 1964)

Stages Features	Larva	Protonymph	Deutonymph	Tritonymph	Adult
Nature of Sensillus	Not developed	<i>Clavate</i>	<i>Clavate</i>	<i>Clavate</i>	<i>Clavate</i>
No of notogastral setae	<i>10 pairs</i>	<i>14 pairs</i>	<i>14 pairs</i>	<i>14 pairs</i>	<i>14 pairs</i>
Epimeral setal formula	<i>2-1-1</i>	<i>3-1-2-1</i>	<i>3-1-3-2</i>	<i>3-1-3-3</i>	<i>3-1-3-3</i>
Number of genital setae	<i>0</i>	<i>1 pair</i>	<i>4 pairs</i>	<i>6 pairs</i>	<i>6 pairs</i>
Number of genital suckers	<i>0</i>	<i>1 pair</i>	<i>2 pairs</i>	<i>3 pairs</i>	<i>3 pairs</i>
Number of adanal setae	<i>0</i>	<i>0</i>	<i>3 pairs</i>	<i>3 pairs</i>	<i>3 pairs</i>
Number of anal setae	<i>0</i>	<i>0</i>	<i>0</i>	<i>3 pairs</i>	<i>3 pairs</i>
Legs	<i>3 pairs</i> <i>Monodactylous</i>	<i>4 pairs</i> <i>Monodactylous</i>	<i>4 pairs</i> <i>Monodactylous</i>	<i>4 pairs</i> <i>Monodactylous</i>	<i>4 pairs</i> <i>Monodactylous</i>
Length/Width (Average)	<i>174/75µm</i>	<i>271/120µm</i>	<i>307/148 µm</i>	<i>328/211 µm</i>	<i>392/266 µm</i>