

Checklist of Indian Tardigrades and its Status Survey

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Abstract: Information on the species diversity of tardigrades and research on tardigrades are scanty India. This species gains attention in present days, due to its highly adaptive ability to tide over the extreme conditions like temperature, pressure and radiation. The study consolidated all the reports of tardigrades present in India and updates the number of species reported from India as 50. Most of the species are reported from the Sikkim and the Andaman Islands. The greater number of species falls under the genera *Macrobiotus*.

Keywords: Tardigrade diversity, Indian species, Water bears

1. Introduction

Water bears or Tardigrades, a group of micrometazoan, was discovered in 1773 and were considered under Phylum Tardigrada by Rammazzotti in 1962. They are distributed in marine, freshwater and terrestrial habitats. Tardigrade with miniature body size consists of body divided into head, trunk and caudal covered with cuticle, buccopharyngeal apparatus and legs terminating with claw/toes which vary in different species. Easily escape from danger by undergoing a phenomenon known as Cryptobiosis which helps them to curb their body parts into a tun stage. Terrestrial species as they are exposed to the fluctuating environment, have the potential to undergo Cryptobiosis. The distribution pattern of tardigrades is the lack of research hinders the development of a precise distribution map and their dispersal is based on their reproductive ability like parthenogenesis has a high success rate. Current era is focusing more on molecular taxonomy for proper species identification. The main aim of the study is to understand the distribution of tardigrades in India and requires effort to explore more areas.

The Phylum Tardigrada consists of 1464 species and 159 genera which is distributed among three classes i.e., Heterotardigrada, Mesotardigrada, and Eutardigrada (Degma & Guidetti, 2023). Heterotardigrada comprises the orders Arthrotardigrada and Echiniscoidea, whereas Eutardigrada comprises the orders Apochela and Parachela. The classes were classified based on morphological character like presence of plates on cuticle and a separate gonopore and anus as in Heterotardigrade or absence of plates and presence of a common cloaca and "Malpighian tubules" as in Eutardigrades. Mesotardigrada is comprised solely of *Thermozodium esakii*, currently considered as *nomen dubium* (Grothman *et al.*, 2017). Further study is needed to assign certain species to the appropriate genus.

The stress environment influences the five cryptobiotic processes that manifest in various forms: anhydrobiosis, cryobiosis, anoxybiosis, osmobiosis, and chemobiosis (Rebecchi *et al.*, 2007; Guidetti *et al.*, 2011; Møbjerg *et al.*, 2011). They produce bioprotectants (Tardigrade disordered proteins, Late embryogenesis-abundant proteins etc) to counteract this stress during the anhydrobiosis process

(Hengherr *et al.*, 2008; Boothby *et al.*, 2017). They can live up more than 30 years without food in tun stage. Heterotardigrade like *Viridiscus* and *Echiniscus brunus* complex (Dey *et al.*, 2023 a) and Eutardigrades like *Paramacrobiotus* BLR strain (Suma *et al.*, 2020), *Paramacrobiotus richtersi* and *Ramazzottius oberhaeuseri* (Altiero *et al.*, 2011) are UV-tolerant. Based on the species tolerance to stress its potential can be applied in biotechnology, environmental monitoring, and space research.

The enigmatic nature of the desiccation mechanism continues to baffle scientists. The utilization of the anhydrobiosis mechanism to transport vaccines to remote locations in a desiccated state and preserve biological materials can endure for years. Due to its capacity to shield DNA from radiation and desiccation, tardigrade has found increased utility in cancer research, particularly in the realm of radiotherapy. According to Kasianchuk *et al.* (2023), the tardigrade disordered proteins (Dsup, CAHS, SAHS, MAHS) and Late embryogenesis-abundant proteins isolated from tardigrade can be applied in biomedical and pharmacological development. The benefits of a damage suppressor (Dsup) include defence against radiation and oxidative stress. The use of cytoplasmic abundant heat-soluble proteins (CAHS) includes the preservation of enzymes, cells, therapeutic proteins, novel anti-apoptotic agents, and the development of dry vaccination platforms. Mitochondrial Abundant Heat Soluble proteins (MAHS) used for preservation of cells. Late embryogenesis-abundant (LEA) proteins can be used for preservation and long-storage of cells.

Status of Indian Tardigrade research

Only limited reports have been recorded from various regions of India like Sikkim, Andaman Islands, West Bengal, Assam, Meghalaya, Tamil Nadu, Goa, Himachal Pradesh, Kerala, Odisha, Uttarakhand and Ladakh. For the majority of the species discovered has no comprehensive taxonomic descriptions in India. Murray (1907) and Iharos (1969) were the pioneers of research in the early 20th century regarding the tardigrade fauna of India.

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India is home to a total of 41 species, 23 of which have been documented in Darjeeling, according to a report by the Zoological Survey of India (Dey & Mandal, 2018). Currently, from India, 50 species have been identified to date. *Milnesium longiunge* is the only one of the five novel *Milnesium* species that Tumanov (2006) found in India (Ladakh). Tumanov (2018) published the first description of a freshwater tardigrade (*Pseudobiotus kathmanae* Nelson, Marley & Bertolani, 1999) from Himachal Pradesh. Bhakare and Pai (2021) recently investigated the density and diversity of the freshwater tardigrade fauna inhabiting the Western Ghats. Vishnudattan *et al.* (2021) documented the discovery of a novel species, *Stygarctus keralensis*, which is classified within the Stygarctidae family, in the intertidal zone of Kerala.

At present, the limnoterrestrial species are the subject of only a limited number of scholarly articles, including those by Maucci (1979), Maucci & Durante Pasa (1980), Kristensen (1987), Abe & Takeda (2000), Tumanov (2006), Jørgensen *et al.* (2007), Coughlan & Stec (2019), Gąsiorek *et al.* (2021), and Basu *et al.* (2023). In a study published in 2007, Jönsson *et al.* looked at COI sequences from *Echiniscus cf. testudo* specimens from Ladakh and found that they were much more diverse than sequences from Greenland, Europe, the Middle East, and North Africa.

In summary, India is home to a limited number of eutardigrade species and approximately ten reliably documented heterotardigrade species. Up until this point, South India has yielded scant reports of its fauna. Nevertheless, there has been a lack of comprehensive

research examining the biodiversity of this particularly resilient animal phylum in India for the past twenty years. Research on tardigrades is currently flourishing on the Indian subcontinent. The present study reviews the Indian tardigrade research and presents an updated checklist of tardigrades so far reported from India.

2. Methodology

The following papers were referred for the checklist: Murray, 1907; Schulz, 1951; Rao, 1971; McInnes, 1994; Abe and Takeda, 2000; Shil, 2001; Tumanov, 2006; Chandra *et al.*, 2018; Coughlan and Stec, 2019; Abirami *et al.*, 2021; Gąsiorek, Vončina, Ciosek *et al.*, 2021; Vishnudattan *et al.*, 2021; Basu *et al.*, 2023; Degma and Guidetti, 2023; Dey *et al.*, 2023 a; Dey *et al.*, 2023 b; Vishnudattan *et al.*, 2023. Degma and Guidetti (2023) checklist was referred for the changed taxa as for the current checklist preparation.

3. Results

Approximately 38% of tardigrades are identified from Sikkim and 20% from Andaman Islands (Fig 1). The least studied areas are Goa, Himachal Pradesh, Kerala, Odisha, Uttarakhand, Ladakh, Assam and Meghalaya with only 1-3 species discovered so far. Figure 1 represents the proportion of different tardigrade species reported from various Indian states. The updated checklist of the species reported from India is consolidated in table 1. It is clear that most of the species recorded from India belongs to *Macrobiotus* genus.

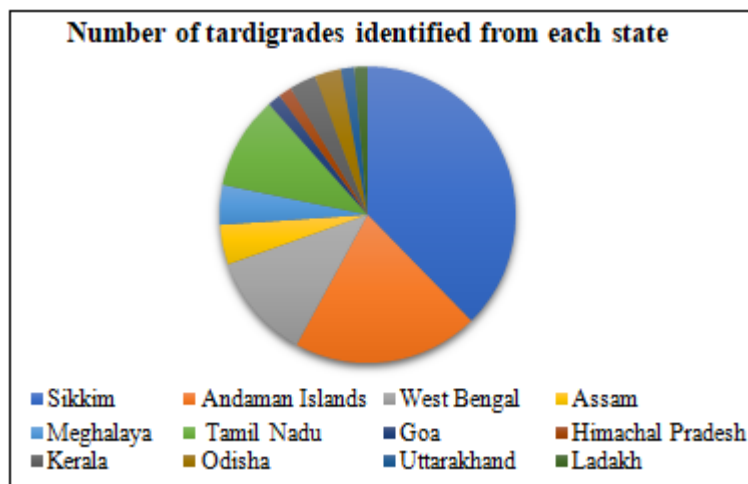


Figure 1: Proportion of different tardigrade species reported from various Indian states.

Table 2: Updated checklist of Indian Tardigrades from different Location

S.No	Species Name (Authors who reported it from India)	Locality from where it is reported
1	<i>Adropion scoticum</i> (Chandra <i>et al.</i> , 2018)	Sikkim
2	<i>Batillipes carnonensis</i> (Rao, 1971)	Odisha
3	<i>Batillipes kalami</i> (Vishnudattan <i>et al.</i> , 2023)	Tamilnadu
4	<i>Bryodelphax ortholineatus</i> (McInnes, 1994)	Andaman Island
5	<i>Calcarobiotus gildae</i> (McInnes, 1994)	Andaman Island
6	<i>Claxtonia wendti</i> (Chandra <i>et al.</i> , 2018)	Sikkim
7	<i>Cornechiniscus madagascariensis</i> (Abe and Takeda, 2000)	Himachal Pradesh
8	<i>Dactylobiotus macronyx</i> (Chandra <i>et al.</i> , 2018)	Sikkim
9	<i>Dianeac acuminata</i> (Chandra <i>et al.</i> , 2018) (Degma and Guidetti, 2023)	Sikkim Tamil Nadu
10	<i>Dianeac sattleri</i> (Chandra <i>et al.</i> , 2018)	Sikkim

11	<i>Diphascos chilense</i> (Murray, 1907) (Chandra <i>et al.</i> , 2018)	Sikkim
12	<i>Diphascos pingue</i> (Chandra <i>et al.</i> , 2018)	Sikkim
13	<i>Echiniscus arctomys</i> (Murray, 1907) (Chandra <i>et al.</i> , 2018)	Sikkim
14	<i>Echiniscus brunus</i> (Dey <i>et al.</i> , 2023 a)	Tamil Nadu
15	<i>Pseudechiniscus suillus</i> (Murray, 1907) (Degma and Guidetti, 2023)	Sikkim
16	<i>Echiniscus quadrispinosus</i> (Chandra <i>et al.</i> , 2018) (Murray, 1907)	Sikkim West Bengal
17	<i>Echiniscus testudo</i> (Degma and Guidetti, 2023) (Murray, 1907)	Assam Meghalaya West Bengal
18	<i>Hypsibius convergens</i> (Degma and Guidetti, 2023)(Chandra <i>et al.</i> , 2018)	Andaman Islands Sikkim
19	<i>Kristenseniscus kofordi</i> (McInnes, 1994)	Andaman Island
20	<i>Macrobiotus echinogenitus</i> (Chandra <i>et al.</i> , 2018) (Murray, 1907)	Sikkim West Bengal
21	<i>Macrobiotus gemmatus</i> (Chandra <i>et al.</i> , 2018)	Sikkim
22	<i>Macrobiotus hufelandi</i> (Degma and Guidetti, 2023) (Shil, 2001) (Chandra <i>et al.</i> , 2018) (Murray, 1907)	Assam, Meghalaya, Sikkim, West Bengal
23	<i>Macrobiotus kamilae</i> (Coughlan and Stec, 2019)	Uttarakhand
24	<i>Macrobiotus polyopus</i> (McInnes, 1994)	Andaman Island
25	<i>Macrobiotus rubens</i> (Chandra <i>et al.</i> , 2018)	Sikkim
26	<i>Macrobiotus sapiens</i> (Abirami <i>et al.</i> , 2021)	Tamil Nadu
27	<i>Macrobiotus topali</i> (Chandra <i>et al.</i> , 2018)	Sikkim
28	<i>Mesobiotus coronatus</i> (McInnes, 1994)	Andaman Island
29	<i>Mesobiotus furciger</i> (McInnes, 1994)	Andaman Island
30	<i>Mesobiotus harmsworthi</i> (McInnes, 1994)	Andaman Island
31	<i>Mesobiotus maucii</i> (McInnes, 1994)	Andaman Island
32	<i>Milnesium tardigradum tardigradum</i> (McInnes, 1994) (Chandra <i>et al.</i> , 2018) (Abirami <i>et al.</i> , 2021)(Murray, 1907)	Andaman Island, Sikkim, Tamil Nadu, West Bengal
33	<i>Milnesium longiungue</i> (Tumanov, 2006)	Ladakh
34	<i>Milnesium sp.</i> (Koshy & Sanil, 2022)	Tamilnadu
35	<i>Minibiotus aculeatus</i> (McInnes, 1994) (Chandra <i>et al.</i> , 2018) (Murray, 1907)	Andaman Island, Sikkim, West Bengal
36	<i>Minibiotus furcatus</i> (Degma and Guidetti, 2023)(Shil, 2001) (Murray, 1907)	Assam, Meghalaya, West Bengal
37	<i>Minibiotus intermedius</i> (McInnes, 1994) (Chandra <i>et al.</i> , 2018)	Andaman Island, Sikkim
38	<i>Nebularmis indicus</i> (Gašiorek, Vončina, Ciosek <i>et al.</i> , 2021)	Goa
39	<i>Nebularmis reticulatus</i> (Murray, 1907) (Chandra <i>et al.</i> , 2018)	Sikkim
40	<i>Paramacrobiotus areolatus</i> (Murray, 1907)	Sikkim
41	<i>Paramacrobiotus bengalensis</i> (Basu <i>et al.</i> , 2023)	West Bengal
42	<i>Paramacrobiotus chieregoi</i> (McInnes, 1994)	Andaman Island
43	<i>Paramacrobiotus richtersi</i> (McInnes, 1994) (Chandra <i>et al.</i> , 2018) (Abirami <i>et al.</i> , 2021)	Andaman Island Sikkim Tamil Nadu
44	<i>Pseudechiniscus (Meridioniscus) juanita</i> (Chandra <i>et al.</i> , 2018) (Gašiorek, Vončina, Zajač <i>et al.</i> , 2021)	Sikkim
45	<i>Ramazzottius oberhaeuseri</i> (Chandra <i>et al.</i> , 2018)	Sikkim
46	<i>Ramazzottius aff. szeptyckiisp. can</i> (Dey <i>et al.</i> , 2023 b)	Tamil Nadu Kerala
47	<i>Stygarctus keralensis</i> (Vishnudattan <i>et al.</i> , 2021)	Kerala
48	<i>Stygarctus bradypus</i> (Rao, 1971) (Schulz, 1951)	Odisha
49	<i>Testechiniscus macronyx</i> (Murray, 1907)	Sikkim
50	<i>Ursulinius mihelcici</i> (Chandra <i>et al.</i> , 2018)	Sikkim

4. Discussion

Murray (1907) and Iharos (1969) emerged as trailblazers in the early 20th century with regard to investigations concerning the tardigrade fauna of India. Fourteen species of limnoterrestrial tardigrades were documented in Sikkim. The only data derived from South India was obtained from the intertidal dunes along the Waltair coast and the Andaman and Nicobar Islands, an Indian archipelago located in the Bay of Bengal (Rao & Ganapati, 1968; Rao, 1972; Rao, 1980). Maucii and Durante Pasa (1980) conducted an examination of several samples of interstitial tardigrade moss that were procured from the Andaman Islands.

According to a study by the Zoological Survey of India, 23 of the 41 species that call India home reside in Indian Himalaya (Dey & Mandal, 2018). The review updates the number of tardigrades to 50 from India. Majority of the tardigrades has been discovered from Sikkim and Andaman Islands. In 2023, four new species have identified *Batillipes kalami*, *Echiniscus brunus*, *Ramazzottius aff. szeptyckiisp. can* and *Paramacrobiotus bengalensis*. More species are left to be discovered and certain areas are still unexplored.

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