



RESEARCH ARTICLE

# Bryofloristic account of the genus *Riccia* L. from Girnar Wildlife Sanctuary, Gujarat

Bhagyashri V Dangar<sup>1,2</sup> & Rajesh Raviya<sup>1\*</sup>

<sup>1</sup>Department of Life Sciences, Bhakta Kavi Narsinh Mehta University, Junagadh 362 263, Gujarat, India

<sup>2</sup>Centre of Excellence for Wildlife and Conservation Studies, Bhakta Kavi Narsinh Mehta University, Junagadh 362 263, Gujarat, India

\*Correspondence email - [rdraviya@bknmu.edu.in](mailto:rdraviya@bknmu.edu.in)

Received: 26 January 2026; Accepted: 01 June 2026; Available online: Version 1.0: 23 September 2026

**Cite this article:** Dangar BV, Raviya R. Bryofloristic account of the genus *Riccia* L. from Girnar Wildlife Sanctuary, Gujarat. Plant Science Today (Early Access). <https://doi.org/10.14719/pst.13832>

## Abstract

The plant genus *Riccia* L. comprises a highly diverse group of complex thalloid liverworts and accounts for a substantial share of bryophyte diversity. However, the literature indicates that *Riccia* liverworts are widely distributed but little is known about *Riccia* species from semi-arid environments of western India. In this context, this study aims at contributing to the national knowledge repository by carrying out detailed investigation of diversity, habitat preferences, spatial patterns and altitudinal variations of *Riccia* species in the Girnar Wildlife Sanctuary, Gujarat. Surveys were carried out at sixteen selected locations using a systematic sampling design and covered all sampling sites during the monsoon seasons of 2022 and 2023. The diversity of *Riccia* in the study area comprises five species, such as *Riccia billardieri* Mont. & Nees, *Riccia cavernosa* Hoffm., *Riccia discolor* Lehm. & Lindenb., *Riccia gangetica* Ahmad ex L. Söderstr., A. Hagborg & von Konrat. and *Riccia grollei* Udar. Among these recorded species, *R. cavernosa*, *R. discolor* and *R. grollei* are reported for the first time from the study area. Rupicolous, terricolous and saxicolous habitat types are highly dominant, indicating *Riccia* diversity and importance of soil-based and lithophilous environments for *Riccia* colonisation. *Riccia* species richness was found at lower altitudinal slopes (100–400 m) followed by a decline at mid-altitudinal slopes and then a slight increase at higher altitudinal slopes. This study highlights the Bryofloristic significance of Girnar Wildlife Sanctuary and emphasises the role of microhabitat heterogeneity and altitudinal gradients which indicating *Riccia* diversity. These findings contribute valuable baseline data for bryophyte conservation and future ecological assessment in semi-arid regions of India.

**Keywords:** altitudinal gradient; Girnar Wildlife Sanctuary; Gujarat; habitat preference; *Riccia*; species richness

## Introduction

The genus *Riccia* L. (Marchantiales (Order) Ricciaceae (Family)) was discovered in 1729 and later formally recognised in 1753 in Species Plantarum (1). It represents the largest and most diverse genus of complex thalloid liverworts. Globally, it comprises about 152 species, of which 36 species (constituting 24 %) are reported from India (2, 3). In India liverworts diversity constitutes 854 species, 17 subspecies, 135 genera and 56 families (4). Within this, *Riccia* is represented by at least 39 taxa, including species such as *Riccia billardieri* Mont. & Nees, *Riccia cavernosa* Hoffm., *Riccia crystallina* L., *Riccia discolor* Lehm. & Lindenb., *Riccia fluitans* L., *Riccia frostii* Aust., *Riccia gangetica* Ahmad ex L. Söderstr., *Riccia grollei* Udar, *Riccia huebeneriana* Lindenb., *Riccia melanospora* Kashyap. and *Riccia stricta* (Gottsche, Lindenb. & Nees) Perold. (3). In Gujarat, 26 species of liverworts have been reported (5–7).

Members of Ricciaceae are morphologically distinct, are characterised by dorsiventrally flattened, strap-shaped gametophytic thalli that exhibit dichotomous (Y shaped) branching, either symmetrical or asymmetrical (8). The thalli are anatomically differentiated into upper photosynthetic region and a lower storage zone and may possess simple pores like other thalloid liverworts. Unique reproductive features of *Riccia* include the absence of seta and foot, cleistocarpus sporophytes lacking elaters and capsules

embedded within the gametophytic tissue. The sporophytes are typically produced singly and show anacrogynous development, devoid of protective structures such as the pseudoperianth (9).

In Gujarat, nine species of *Riccia* have been documented, namely, *R. billardieri*, *R. discolor*, *R. gangetica*, *R. crystallina*, *R. cavernosa*, *R. grollei*, *Riccia cruciate* Kashyap., *R. melanospora* and *Riccia okahandjana* S.W. Arnell. (6, 7, 10). These species exhibit a wide ecological range, colonising diverse substrates such as rock crevices, tree bark, decaying wood, wall surfaces and disturbed soils (11). In eastern central Gujarat comprising five districts, viz Dahod, Panchmahal, Narmada, Vadodara and Chhotaudepur, four species of *Riccia* have been reported. Studies have shown that in Junagadh district of Gujarat, where the current study area is located, researchers have documented two species of *Riccia* (5). Liverworts remain among the least explored plant groups due to their minute thalloid structure and taxonomic complexity (12). Despite the recognised ecological importance of liverworts, particularly members of the genus *Riccia*, their diversity and distribution in semi-arid region of western India, in Gujarat, especially the Saurashtra peninsula, is characterised by heterogeneous microhabitats influenced by seasonal rainfall and varied soil conditions; however, bryological investigations in this region have been largely limited to sporadic reports and checklist-based studies. The lack of detailed ecological and distributional data creates a

significant knowledge gap in understanding species occurrence, habitat specificity and their response to semi-arid climatic conditions.

## Materials and Methods

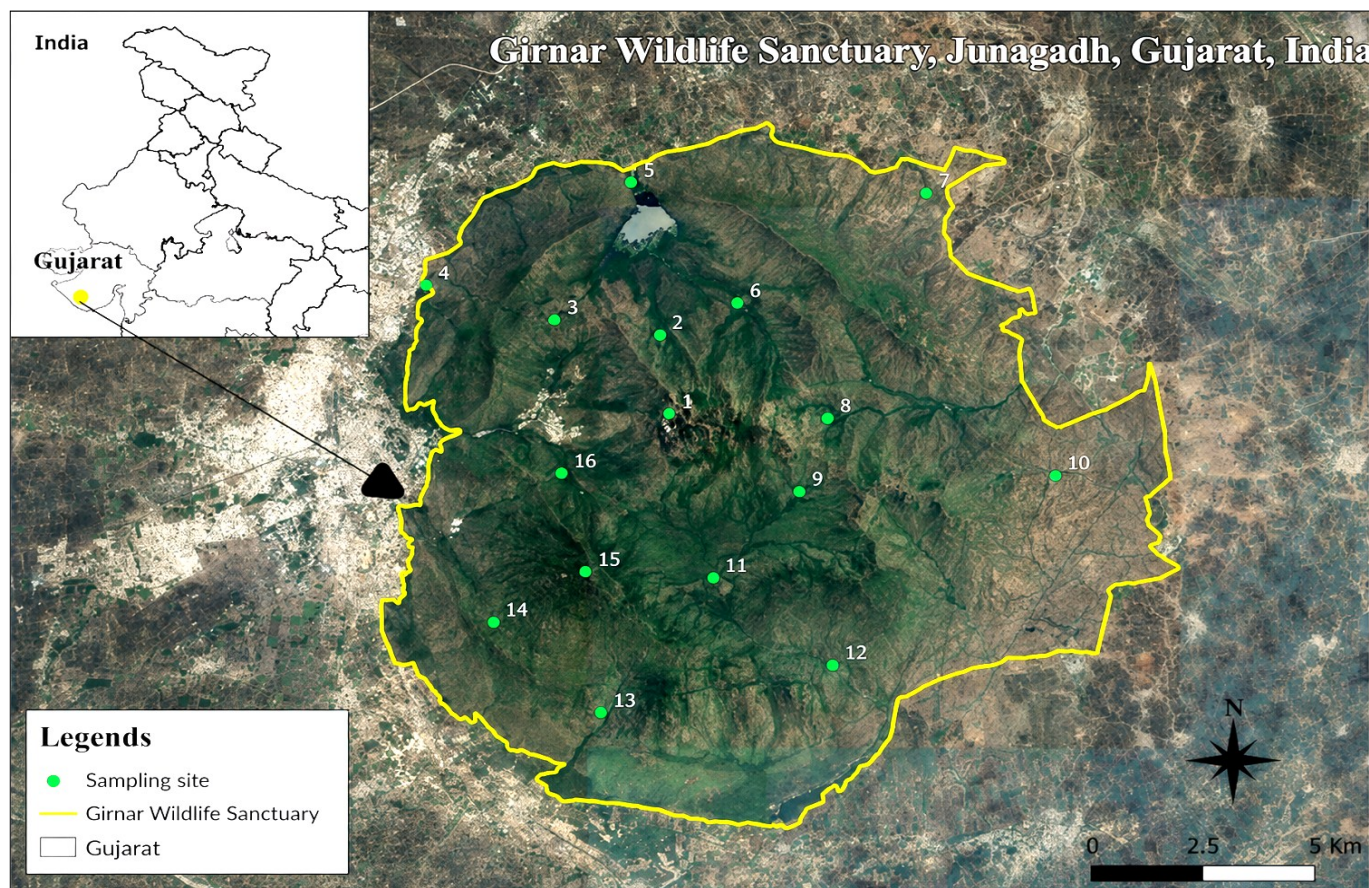
### Study area

Girnar Wildlife Sanctuary is situated in the Gujarat, western India, between latitude 21°25' N to 21°35" and 70°30' E to 70°40' E (Fig. 1). It falls within the Gujarat-Rajputana biotic province Zone 4B of the semi-arid biogeographic zone (13). The forest type of the study area is classified as Southern Tropical Dry Deciduous Forest, subtype VII-A/C1 (14). The study area possesses high flowering plant diversity, with 537 vascular plant species recorded (15). Topographically, the Girnar hill varies altitudinal range from about 82 m above mean sea level (AMSL) to 1119 m at the peak of Goraknath, which is the highest point of Girnar Wildlife Sanctuary. The varied physiography results in diverse microhabitats viz steep escarpments that are sparsely vegetated, while valleys, riverbeds and reservoir beds that harbour distinct ecological communities, also has a network of rivers viz Hiran, Saraswati, Datardi, Shingoda, Macchundi, Ghodavadi and Raval rivers.

Comprehensive field investigations were undertaken at sixteen strategically selected locations within Girnar Wildlife Sanctuary to assess the diversity of thalloid liverworts, with particular emphasis on the genus *Riccia* (Fig. 1). Site selection was based on the representation of major topographic and climatic gradients across the sanctuary, which includes heterogeneous mountainous and flat terrain types. Field surveys were conducted during two monsoonal

phases: July–September 2022 and July–September 2023. All field work was done under official permit from Gujarat Forest Department (Letter No.: WLP/RTC/28/C/433-434/2022-23) under the provisions of the Indian Wildlife (Protection) Act 1972.

The study area covered in the area of Sanctuary was systematically surveyed using a grid-based sampling approach, the region was divided into 1 km<sup>2</sup> grids to ensure uniform spatial coverage and minimise sampling bias using global positioning system (GPS) mapping techniques (Garmin etrex 10). With the help of quantum geographic information system (QGIS), random sampling points were created in the area. A total of 50 random sampling points were created in that area across different altitudinal ranges and habitat types, covering micro-habitats such as wet rocks, tree trunks, open soils, resting soils, etc. At each sampling point, detailed surveys were conducted for the presence of *Riccia* species. *Riccia* colonies were systematically collected using scalpel in paper bags to carry from field to laboratory, along with ecological metadata collection on the sampling site. Geographic coordinates were noted for each collection site to facilitate spatial analysis of distribution patterns. Identification of species are done by morphological and anatomical characteristics and using standard bryophyte floras. Species diversity was quantified using PAST software to assess species dominance and richness. Altitudinal distribution patterns were analysed by grouping sampling locations into elevation classes and examining species occurrence across there gradients. This methodological framework enables comprehensive sampling across the sanctuary's varied microclimatic zones and terrain types supporting a robust assessment of *Riccia* diversity and habitat specificity.



**Fig. 1.** Map of study area (Girnar Wildlife Sanctuary) with selected sampling sites (S1: Sevadas; S2: Nakhali; S3: Joganiya; S4: Indreshwar; S5: Jambudi; S6: Jinabava madhi; S7: Paturan; S8: Marvela; S9: Nalpani; S10: Kala Gadba; S11: Bordevi; S12: Ramnath; S13: Khodiyar; S14: Datar; S15: Navnath; S16: Kashmiri bapu).

## Results and Discussion

The present findings gain strong support when viewed in the context of earlier bryological studies conducted in Gujarat and the Saurashtra region. Previous documentation of *Riccia* species from Gujarat is relatively limited. Earlier reports from the state recorded four species, out of which only *R. billardieri* was known from the Saurashtra region. Similarly, the bryophyte survey reports from Junagadh district reported a total of 21 bryophyte species, with only two *Riccia* species, namely *R. billardieri* and *R. gangetica*, which represents a low representation of the genus in earlier accounts (6).

Further studies reported the occurrence of two *Riccia* species from the Saurashtra peninsula (10). Against this background, the present study significantly expands the known diversity of *Riccia* within Gimar Wildlife Sanctuary by documenting five species, including *R. cavernosa*, *R. discolor*, *R. grollei*, as new records for the region. However, this species is recorded from Central Gujarat (5). Recently one more addition of *R. okahandjana* from the Gimar Wildlife Sanctuary was reported (7). These results are consistent with those from other less explored parts of the country, where increased and intensive research activities have led to a new discovery of bryophytes (16). In addition to taxonomic description, the study highlights their microhabitat preferences and altitudinal distribution pattern of *Riccia* species. From biogeographical perspective, the occurrence of these species in the study area suggests that the lower to mid-elevation zones of semi-arid landscape can serve as important refugia for liverwort diversity.

### Habitat preference

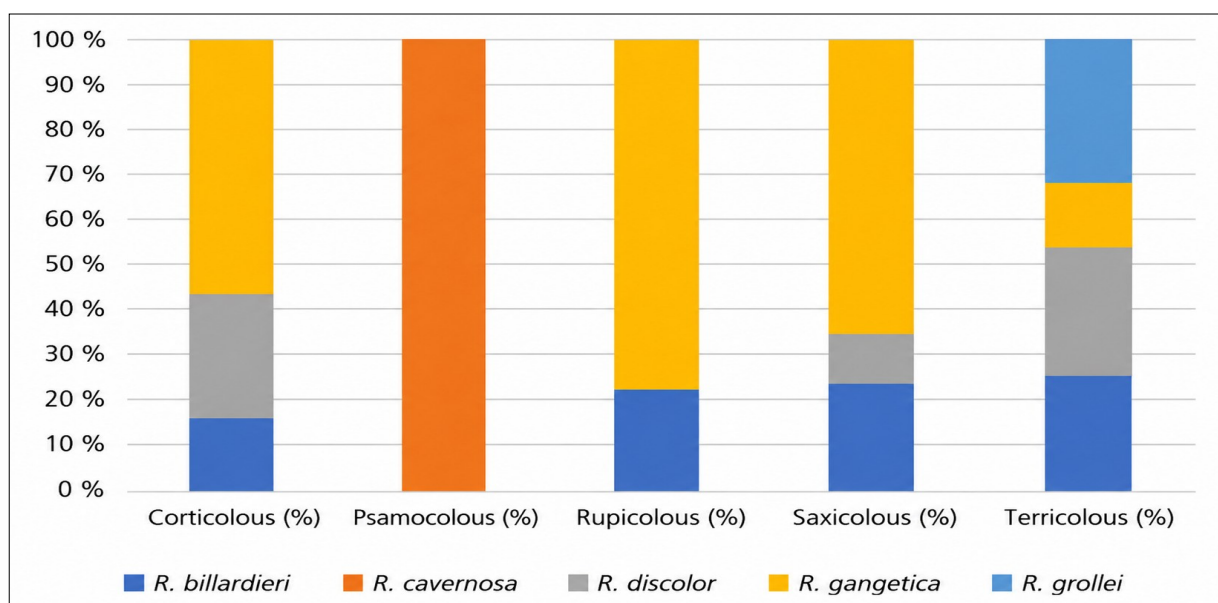
Terricolous, saxicolous, rupicolous, corticolous and psammophilous are five distinct habitat types for occurrence of *Riccia* species in the study area reflects the high degree of habitat heterogeneity and micro-environmental diversity within the sanctuary (Fig. 2). Habitat preference of *Riccia* species revealed a strong dominance of terricolous habitat accounting for 78 % of the total observation, followed by saxicolous habitats (16.8 %), Corticolous (1.6 %), psamocolous (1.6 %) and rupicolous (1.1 %). Such habitats provide suitable microclimatic conditions including moisture retention, shaded niches and favourable substrate texture, which are critical for establishment of thalloid liverworts. *Riccia billardieri* showed a marked affinity towards the terricolous substrate (81.3 %), with

moderate occurrence on rocks (saxicolous habitat) (16.5 %) with minimal occurrence with corticolous and rupicolous condition. *Riccia discolor* was predominantly terricolous (91.2 %), with limited occurrence on rocks (7 %), *R. gangetica* exhibited a relatively broader distribution, occurring in both terricolous (48.1 %) and saxicolous (44.4 %) habitat, with minor presence on other habitats. *Riccia cavernosa* was exclusively recorded from sandy habitat near riverbank and watery areas with psammophilous habitats (100 %), indicating strong substrate specificity, whereas *R. grollei* was restricted to terricolous habitats (100 %).

The dominance of terrestrial *Riccia* taxa corroborates earlier observations that terrestrial liverworts commonly colonise specialised habitats such as moist soil surface, soil covered rocks, shaded or exposed rocky substrates and extremely wet rock surface (17). Habitat partitioning observed in the present study appears to be governed by niche segregation, where individual species occupy specific substrata based on microhabitat characteristics such as moisture availability, light exposure and substrate stability. Similar pattern of substratum-based segregation has been reported in bryophyte communities from other regions of Indian subcontinent (18, 19).

### Species dominance and spatial distribution

Quantification showed that species dominance and distribution patterns varied significantly in the sanctuary. *Riccia billardieri* was recorded to be the dominant species in terms of distribution, recorded in 15 out of the 16 sites, denoting a wide ecological amplitude with its high adaptability to a wide range of environmental conditions. On the other hand, *R. cavernosa* showed a narrow ecological amplitude given its limited distribution, recorded in only two sites, suggesting strong specificity to a particular microhabitat, specifically a moist rupicolous environment. The present record of *R. billardieri*, *R. cavernosa*, *R. discolor* and *R. gangetica* align with earlier reports from monsoon tropical regions of Northern Territory, Australia (20) and West Bengal (21). The occurrence of *R. billardieri*, *R. discolor*, and *R. gangetica* has also been documented from the Terai region of Uttar Pradesh, India (22), further supporting the wide distribution of these species across diverse geographical regions of the country. This overlap suggests a broader distributional range and highlights the ecological flexibility of these species across diverse habitats in India and beyond the Indian subcontinent.



**Fig. 2.** Percentage distribution of *Riccia* species across different habitat types in study area.

This site-wise variability with regard to species composition further underlines the heterogeneity associated with habitats of Bryophytes at Girnar Wildlife Sanctuary site. Site S1 harboured all five species of *Riccia*, reflecting favourable conditions for substrates, moisture and microclimatic stability, while at many other sites, their number was reduced due to unfavourable conditions.

#### Altitudinal distribution and species richness pattern

The altitudinal range of *Riccia* species found in the sanctuary extends through a broad ecological range from lowland plains to high-altitude habitats, indicating the great ecological amplitude of the genus (Table 1). Higher species richness was found to occur at lower altitudes (100–400 m), as warm and humid environments, which prevail in the range, favour the development of thalloid liverworts. *Riccia cavernosa* had restricted altitudinal range, showing minimal ecological adaptability (Supplementary Fig. 1), while the wide altitudinal range of *R. discolor* and *R. billardieri* indicates their high ecological plasticity (Supplementary Fig. 2 and 3). The bimodal distribution of species like *R. gangetica* and *R. grollei* indicates the ability of these species to tolerate contrasting ecological conditions, which were present at lower as well as at high altitudes (Supplementary Fig. 4 and 5).

The pattern that is followed in this case i.e., richness in lower elevations, followed by a decrease at mid-elevations may reflect transitional environmental conditions and then an increase at higher elevations appear to provide favourable microhabitats for *Riccia* species as a result of some species present that are tolerant, has been established in previous studies that showed that species richness in bryophytes does not always vary in a linear fashion with

**Table 1.** Altitudinal distribution of *Riccia* species in Girnar Wildlife Sanctuary

| Species                   | Low altitude | Moderate altitude | High altitude |
|---------------------------|--------------|-------------------|---------------|
| <i>Riccia cavernosa</i>   | ✓            |                   | ✓             |
| <i>Riccia discolor</i>    | ✓            | ✓                 | ✓             |
| <i>Riccia gangetica</i>   | ✓            |                   | ✓             |
| <i>Riccia billardieri</i> | ✓            | ✓                 | ✓             |
| <i>Riccia grollei</i>     | ✓            | ✓                 | ✓             |

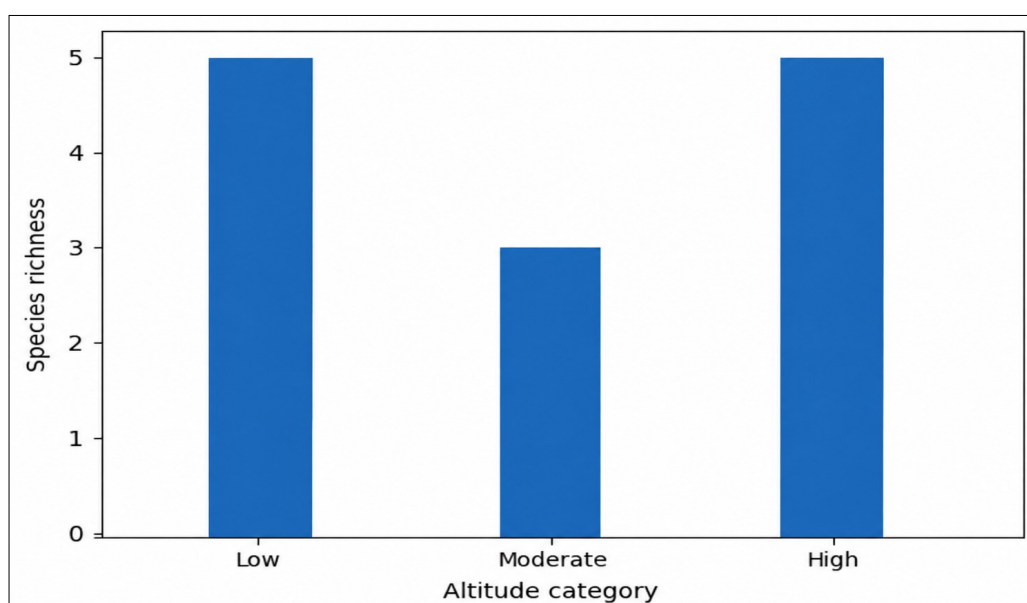
Low altitude (< 400 m); moderate altitude (401–700 m); high altitude (above 700 m).

elevations. The graphical representation clearly illustrates this pattern of species richness across altitudinal gradients (Fig. 3). Thalloid liverworts dominate lower elevations while leafy liverworts dominate higher elevations as elevation increases. This is because of factors like temperature, moisture and light.

Also, several research works have emphasised that species richness patterns, along with elevational gradients, are controlled by many factors, not just elevation itself. It is considered that bryophyte species richness may be positively correlated with woody plant diversity, which enhances microhabitat heterogeneity and moisture retention. Similarly, temperature and climatic factors play important roles in shaping plant community structure at higher elevations (23). Also, resource availability and physiological constraints as key determinants of local species richness. The high species richness recorded in the lower to mid-elevational sites in the present study may, therefore, be related to the presence of optimum temperature and moisture regimes, along with a diversity of soil characteristics and biotic interactions (24). The occurrence of *R. cavernosa*, *R. billardieri*, *R. gangetica* and *R. discolor* is also consistent with global taxonomic reviews of the family, which report these species from diverse regions worldwide, highlighting their broad geographical range and ecological adaptability (25).

#### Conclusion

Girnar Wildlife Sanctuary stands out as a hotspot for *Riccia* species in Saurashtra. The study found six different species, including new regional records, which means *Riccia*'s range in western India has expanded. Interestingly these plants aren't just scattered randomly, but they seem to pick their spots based on soil type, substrate, humidity and sunlight (partial or direct). Most *Riccia* species stick to lower and mid-elevation areas. These zones are where liverwort diversity thrives. The small changes in climate and soil from one patch to another does matter. All these points to a need for detailed, site-by-site bryophyte surveys to understand changes in regional diversity. Research on population changes over time, measure the specifics of their environments and molecular tools to clear up any confusion in *Riccia*'s taxonomy should be done.



**Fig. 3.** Species richness of *Riccia* across different altitudinal zones.

## Acknowledgements

The authors sincerely thank the Gujarat Forest Department for granting permission to conduct the present study in the protected areas. The authors are grateful to the Deputy Conservator of Forests (DCF) and all the forest staff of the Junagadh Forest Division for their constant support and cooperation during the fieldwork. Special thanks are extended to Dr. Rakesh Gujar for his valuable suggestions and continuous support.

## Authors' contributions

BVD conducted field work, collected and analysed the data and prepared the preliminary draft of manuscript. RR supervised the study, monitored the research progress, evaluated the data and provided critical input for improving the manuscript. Both authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors do not have any conflict of interest to declare.

**Ethical issues:** None

## References

- Linnaeus C. *Species Plantarum*. Vol. 2. Stockholm: Laurentii Salvii; 1753. <https://doi.org/10.5962/bhl.title.59734>
- Söderström L, Hagborg A, von Konrat M, Bartholomew-Began S, Bell D, Briscoe L, et al. World checklist of hornworts and liverworts. *PhytoKeys*. 2016;59:1–828. <https://doi.org/10.3897/phytokeys.59.6261>
- Singh SK. An appraisal of genus *Riccia* in India with a note on diversity and distribution of species. *Int J Sustain Water Environ Syst*. 2014;6(1):35–43.
- Majumdar S, Dey M. A handbook on bryophytes with special reference to type specimens of liverworts and hornworts in Indian herbaria. Kolkata: Botanical Survey of India; 2021. p. 274.
- Gujar RV. Diversity and distribution pattern of bryophytes in eastern central Gujarat [PhD thesis]. Vadodara: The Maharaja Sayajirao University of Baroda; 2022.
- Chaudhary BL, Sharma TP, Charu S. Bryophyte flora of Gujarat (India). Udaipur: Himanshu Publication; 2006.
- Wilbraham J, Afanasjeva LV, Ali SN, Álvaro-Alba WR, Aponte-Rojas AM, Bednarek-Ochyra H, et al. New national and regional bryophyte records, 81. *J Bryol*. 2025;47(2):148–63. <https://doi.org/10.1080/03736687.2025.2516912>
- Cargill DC, Neal WC. A preliminary molecular phylogeny of the genus *Riccia* L. (Ricciaceae) in Australia. *Aust Syst Bot*. 2016;29(3):197–217. <https://doi.org/10.1071/SB16018>
- Crandall-Stotler B, Stotler RE, Long DG. Phylogeny and classification of the Marchantiophyta. *Edinb J Bot*. 2009;66(1):155–98. <https://doi.org/10.1017/S0960428609005393>
- Shah DG, Gujar RV. A pilot study on bryophyte diversity and distribution in Gujarat. Gandhinagar; 2015.
- Shah DG, Gujar RV. Diversity and distribution of liverworts in Gujarat current status. *Plant Sci Today*. 2016;3(2):124–8. <https://doi.org/10.14719/pst.2016.3.2.208>
- Devi NP, Yumkham SD, Singh PK. Two new records of *Riccia* L. (Ricciaceae) for the eastern Himalaya bryogeographical region of India. *J Asia Pac Biodivers*. 2019;12(4):626–30. <https://doi.org/10.1016/j.japb.2019.08.005>
- Rodgers WA, Panwar HS. Planning a wildlife protected area network in India. 1988.
- Champion HG, Seth SK. A revised survey of the forest types of India. Manager of publications. 1968.
- Yadaiah G, SA KA. Management plan of Girnar Wildlife Sanctuary. 2014.
- Wilbraham J, Abdirasulov F, Afonina OM, Alvarez DJ, Andrade R, Anurag, et al. New national and regional bryophyte records, 84. *J Bryol*. 2026;48(1):68–81. <https://doi.org/10.1080/03736687.2026.2649051>
- Smith JMB. Ecology of high mountains of New Guinea. In: von Royen P, editor. The alpine flora of New Guinea. Berlin: J Cramer; 1980. p. 111–51.
- Negi HR, Gadgil M. Cross-taxon surrogacy of biodiversity in the Indian Garhwal Himalaya. *Biol Conserv*. 2002;105:143–55. [https://doi.org/10.1016/S0006-3207\(01\)00158-6](https://doi.org/10.1016/S0006-3207(01)00158-6)
- Daniels AED, Kariyappa KC. Bryophyte diversity along a gradient of human disturbance in the southern Western Ghats. *Curr Sci*. 2007;93:976–82.
- Cargill DC, Beckmann K, Seppelt R. Taxonomic revision of *Riccia* (Ricciaceae, Marchantiophyta) in the monsoon tropics of the Northern Territory, Australia. *Aust Syst Bot*. 2021;34(4):336–430. <https://doi.org/10.1071/SB20030>
- Singh SK, Bag AK, Bhattacharya SG. *Riccia* (Hepaticae: Ricciaceae) of West Bengal. Taiwan. 2010;55(2):99–109.
- Sahu V, Asthana AK. Bryophyte diversity in Terai regions of Uttar Pradesh, India with some new additions to the state. *Trop Plant Res*. 2015;2(3):180–91.
- Hamilton AC, Perrott RA. A study of altitudinal zonation in the montane forest belt of Mt. Elgon, Kenya/Uganda. *Vegetatio*. 1981;45(2):107–25. <https://doi.org/10.1007/BF00119220>
- Sánchez-González A, López-Mata L. Plant species richness and diversity along an altitudinal gradient in the Sierra Nevada, Mexico. *Divers Distrib*. 2005;11(6):567–75. <https://doi.org/10.1111/j.1366-9516.2005.00186.x>
- Perold SM. The taxonomic history of the Ricciaceae (1937–1995) and a classification of sub-Saharan *Ricciae*. *Bothalia*. 1995;25(1):211–31. <https://doi.org/10.4102/abc.v25i1.729>

## Additional information

**Peer review:** Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

**Reprints & permissions information** is available at [https://horizonpublishing.com/journals/index.php/PST/open\\_access\\_policy](https://horizonpublishing.com/journals/index.php/PST/open_access_policy)

**Publisher's Note:** Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Indexing:** Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc  
See [https://horizonpublishing.com/journals/index.php/PST/indexing\\_abstracting](https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting)

**Copyright:** © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

**Publisher information:** Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.