



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 9, September 2025

Biodiversity of Algal and Aquatic Plant Species in India: A Review with Special Reference to Rajasthan

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ABSTRACT: Biodiversity plays a pivotal role in maintaining the ecological balance of aquatic ecosystems. India, with its varied climatic zones and extensive network of water bodies, harbors a rich array of algal and aquatic flora, contributing significantly to ecosystem services such as oxygen production, nutrient cycling and habitat provision. Although Rajasthan is predominantly arid and semi-arid, it possesses unique freshwater ecosystems, including rivers, lakes, ponds and man-made reservoirs, which sustain a remarkable diversity of algae and aquatic plants adapted to extreme conditions. Therefore, this review paper focuses on the diversity, distribution and ecological significance of algal and aquatic plant species in India, with special emphasis on the state of Rajasthan.

KEYWORDS: Rajasthan, biodiversity, alga, plants.

I. INTRODUCTION

Biodiversity is fundamental to human survival and economic prosperity. In addition to its ethical and aesthetic values, it offers substantial direct economic advantages. Recent research has focused on the impact of several global change drivers on biodiversity and ecological services. India's study on variety includes floristic diversity, species richness, endemism, varied habitats, angiosperms, vegetation patterns and phytogeographical studies. The diversity of India's flora is due to its topographical characteristics, extensive climate fluctuations and varied habitats that sustain many plant species. Angiosperms include roughly 18,532 of the 49,003 plant species, or 10% of all recognized flowering plants. Leguminosae is the most common angiosperm family, followed by Poaceae, Orchidaceae, Asteraceae and Rubiaceae. Behera and Roy (2019) examined a nationwide database about the diversity of Indian plant species. They presented a preliminary and representative richness map of angiospermic plants, including 7,761 species from 15,565 nested quadrants over latitudinal and longitudinal gradients. According to Singh et al. (2015), there are 4,303 endemic angiosperm species, including 3,170 dicotyledon species across 723 genera, 1,133 monocot species across 254 genera, a 1.5% contribution from pteridophytes and a minimal number of endemic gymnosperm species throughout the estimate period. India has 18,666 angiosperm species, of which 25.67% are indigenous. Among the 2780 species, there are 659 indigenous bryophytes. Algae include 1960 species. Prioritizing conservation efforts for endangered or critically important species facilitates the identification of information deficiencies and the monitoring of advancements. In this perspective, it is essential to acknowledge that aquatic environments serve as crucial stores of biodiversity. Macrophyte diversity is a crucial metric directly associated with altitude, nutrient availability and water quality. Mechanisms regulating species diversity in aquatic habitats have been studied much less than in terrestrial and benthic settings. The species diversity of different aquatic ecosystems has been investigated, revealing that water quality characteristics directly influence plant diversity dynamics. Human-induced factors, such as pollution and habitat modification, tend to promote a greater variety of non-native species relative to native species, thereby altering the ecological balance. Within these aquatic ecosystems, algae play a crucial role, existing in various forms depending on their habitat. Algae that develop as slippery coatings on rock surfaces are referred to as periphyton, while those that remain freely floating in the water column are known as phytoplankton, each contributing differently to the overall biodiversity and ecosystem functioning. Eutrophication may significantly alter rocky coast ecosystems. The prevalence of Chlorophytes and Cryptomonade (phytoplankton) has been seen with low concentrations of phosphorus in aquatic habitats. The diatoms reached significant levels with reduced phosphorus concentrations. Alterations in phytoplankton diversity indicate variations in water quality.

Biodiversity is crucial for human life, economic prosperity and the functionality and stability of ecosystems. The significance of aquatic plant variety for sustained life support is well acknowledged. Despite being regarded as a desert state, Rajasthan has abundant aquatic vegetation and wildlife. The recording and accurate evaluation of aquatic biodiversity rely on specific regions and their habitats. Regrettably, contemporary aquatic habitats are being progressively devastated for several causes. The decline in biodiversity mostly results from habitat degradation, over-exploitation, pollution and the unsuitable introduction of non-native species. The existence of indigenous aquatic species is jeopardized, necessitating focus on aquatic resources. Immediate measures must be implemented for their conservation and sustainable usage. There is a need for enhanced legislative safeguards and well-crafted management strategies to preserve aquatic biodiversity. Priority should be given to the protection of aquatic resources by various governmental and non-governmental groups for the benefit of mankind.

II. REVIEW OF LITERATURE

The Baanganga wetland contains numerous islands of diverse shapes and sizes, submerged during the rainy season, which serve as a suitable habitat for various plant taxa. Babu and Adhikari (2008) evaluated the condition and distribution of flora by expeditions in the intense research area. The plants were categorized according to their growth form and their existence was visually assessed.

Bhardwaj and Bhatnagar (2013) sought to assess the algal variety and water quality in the Chambal River in Kota, Rajasthan. Algal and water samples were taken weekly from several locations upstream and downstream of the River Chambal. This research used Palmer's biotic index to evaluate water quality. The algal flora of four river locations identified 70 species in four groups.

Verma and Khan (2014) provided an overview of aquatic plants studied in several freshwater bodies in the Jhunjhunu area of Rajasthan, India. A field assessment of the research region was conducted to delineate the aquatic variety based on their physical features. A total of 15 aquatic angiosperm plant species, belonging to 11 families, were discovered during the investigation.

Charan and Sharma (2016) conducted a floristic assessment of the Thar Desert from 2013 to 2015. The analysis of vegetative habits revealed that herbaceous vegetation constituted the majority at 60.10%, followed by shrubs at 16.26%, trees at 14.29% and climbers at 9.36% in the Thar Desert.

Nayak et al. (2016) shown that a diverse array of commercially and medicinally significant hydrophytes exists in the water bodies of Bhubaneswar and its surrounding regions. Numerous water bodies were seen to be overrun by hydrophytes such as Eichhornia and Salvinia, resulting in detrimental biological impacts on the aquatic ecology. Repeatedly, human avarice has inflicted detrimental consequences on Nature. One such activity is the use of land for housing, agricultural pursuits and livestock husbandry. Certain portions of wetlands have been drained and converted into rice paddies and used for other agricultural products. This study presented a database of hydrophytes in Bhubaneswar and its surrounding region, which will aid future efforts in conservation, preservation and enhancement of local biodiversity.

Jagetiya and Porwal (2019) conducted research focused on the critical examination of plant species at two locations in Bhilwara city: the southern site (S1) and the western site (S2). Plants were gathered during the research period from January 2016 to December 2016. During the trips, observations of morphological characteristics were documented.

The Tal Chhapar Wildlife Sanctuary is located in the Sujangarh Tehsil in the Churu district in northeastern Rajasthan. This region safeguards a significant number of plant and animal species, including Blackbucks. Bagoriya et al. (2020) cataloged the floristic diversity of this region. The Poaceae family is the most prevalent in the region, followed by Fabaceae, Asteraceae and Cyperaceae.

Sharma (2020) emphasized the extensive aquatic flora of Indergarh tehsil in Bundi district. Indergarh tehsil is a biodiversity-rich region located on the Haroti plateau in southeastern Rajasthan. Aquatic plants are essential for the survival of wildlife and provide promise for sustainable ecosystems. A multitude of plant species is abundantly present in the water bodies located in this region. The results given derived from 2 years of exploration of the aquatic flora in this region.

Patole (2021) examined the floristic variety of water flowering plants, categorized into four distinct groups, namely. The Onagraceae family is considered primitive, whereas the Cyperaceae and Poaceae groups are regarded more

advanced. Taxonomic information has been recorded. The Akot area of Akola district is abundant in permanent lakes, ponds, ditches, rivers and streams, with many of these water bodies teeming with aquatic plants.

Pathak and Rana (2021) sought to ascertain the variety and distribution of alien macrophytic plants in the Arthuna pond located in Garhi Tehsil, Banswara District, South Rajasthan. In 2019 and 2020, specimens were gathered from four locations distributed over the research region, spanning north to south and east to west. Seven species from six genera and six families are identified as Invasive Alien Macrophytes. Physicochemical characteristics such as water pH, temperature, total dissolved solids (TDS), dissolved oxygen and turbidity were analyzed throughout three seasons: winter, summer and rainy. The Invasive Alien Species pose a significant danger to local biodiversity and human health; hence, a thorough research of invasive plant species is essential.

Zode et al. (2021) conducted research to examine the variety of aquatic plants in five chosen lakes around Gondia city. To do this, well designed surveys were conducted regularly at designated locations. During visits, data on habits, lifespan, local nomenclature and life forms of all plant species present in the aquatic environment were obtained. In the research, 44 species from 37 genera across 26 groups were documented at chosen locations.

Gulhane et al. (2022) sought to investigate the floral variety of three lakes in Bangalore: Agara, Madiwala and Kaikondrahalli. Certain aquatic plants are sensitive to pollution and serve as bioindicators. The light-yellow coloration of *R. communis* in Madiwala Lake indicates a higher level of pollution in the area compared to the Agara region. The implementation of lake restoration initiatives has partially rehabilitated ecosystems and biodiversity. A collaborative endeavor among ecologists, hydrologists, policymakers and local inhabitants is essential to mitigate adverse human effects and enhance the efficacy of nature reserves and lake restoration efforts.

Paul (2022) analyzed aquatic plant variety in twenty ponds in the Thrissur area of Kerala from April 2014 to March 2016. Throughout the research period, 41 macrophytes were identified, including 35 taxa from 24 groups, including Pteridophytes.

Meena and Rathore (2023) encapsulated the findings of a comprehensive investigation of the aquatic and wetland vegetation of Panchana Dam and its vicinity. This study provides current and pertinent information on the identification of hydrophytes and wetland flora in the area. The watery and wetland flora consists of 112 species of angiosperms from 101 genera and 50 families. The ratio of monocots to dicots among families was 1:2.6. The five predominant families of hydrophytes were Poaceae, Cyperaceae, Asteraceae, Scrophulariaceae and Fabaceae. Additionally, two species of water ferns (Pteridophytes) identified were *Marsilea minuta* and *Azolla pinnata*.

Sharma and Bamanian (2023) detailed the macrophytic variety of the significant water body, Panchana Dam, located in Karauli city within the Karauli area of eastern Rajasthan. The Panchana dam has a diverse array of aquatic and marsh flora in two locations throughout several seasons. A total of 27 aquatic vegetation groups have been documented, including 24 angiosperms, two Pteridophytes and one alga. Species diversity was greatest in summer, followed by winter and finally monsoon. The indicator macrophytes were *Ceratophyllum demersum* and *Ipomea aquatica*. *Fistulosa*, *Lemna*, *Potamogeton*, *Spirodela*, *Trapa* and *Typha* were identified as predominant species throughout the summer. Macrophyte habitats include free-floating, rooted floating, submerged, muddy, marshy and wet soil environments. The comprehensive list of plant species, including their botanical names, families and descriptions, was provided. The composition of aquatic vegetation in Panchana Dam varied throughout seasons owing to nitrogen enrichment from anthropogenic activities and sewage discharge into the lake.

Gautam et al. (2024) examined the temperature and growth length of several Thallophytes, Pteridophytes and Angiospermic aquatic and semi-aquatic plants from different families throughout the year. The predominant Thallophytes identified were *Spirogyra* and *Chara*, while the Pteridophytes included *Marsilea* and *Azolla*. The Angiospermic families included Cyperaceae, Nymphaeaceae, Trapaceae, Typhaceae, Nelumbonaceae, Lamnaceae, Hydrocharitaceae, among others. These families of distinct species exhibit intense growth at different intervals throughout the year.

Jena et al. (2024) evaluated the aquatic vegetation in the Jajpur district of Odisha. The study was executed throughout several aquatic habitats in the industrial zones of Jajpur district from 2021 to 2023, with the objective of cataloging the

region's unique aquatic ecosystems. Comprehensive investigations were conducted to identify and categorize water plants, with voucher specimens collected and herbaria created according to recognized standards. The study identified 84 species of aquatic and wetland plants across 55 genera and 31 families. The list included 44 marsh species, 18 amphibious species, 3 submerged species, 10 free-floating species and 9 fixed-floating species. These plants fulfill the fundamental requirements of the local population while also significantly contributing to the natural equilibrium of the region.

III. MEDICINAL PROPERTIES OF TRADITIONAL MEDICINAL PLANTS

Traditional herbal medicine is practiced worldwide as indigenous medicine. The use of medicinal plant resources for curing human illnesses coincides with the emergence of human civilization and constitutes the foundation of contemporary medicine's origins. The increasing prevalence of herbal medicines and other complementary therapies prompted the establishment of the Office of Alternative Medicine by the National Institutes of Health, USA, in 1992. Herbal medicine gained global prominence when the World Health Organization advocated for poor nations to use traditional plant-based remedies to address demands inadequately fulfilled by contemporary medical systems. Herbal medicine is used by 75–80% of the global population, mostly in underdeveloped nations for basic healthcare. Furthermore, herbal medications are considered to be devoid of adverse effects, economical and readily accessible.

The use of plants for the treatment of human illnesses dates back to the inception of human civilization. The Indian medical systems, including Ayurveda, Unani and Sidha, use a diverse array of plants in their therapeutic and prophylactic formulations. The resurgence of interest in herbals as sources of cosmetics, medicines, toners, rejuvenators, detoxifiers and anti-aging agents has unveiled new avenues for study in their botany, cultivation, chemistry and clinical standards. These plants are also being investigated for the development of pharmaceuticals to treat disorders for which allopathic medicine has found no adequate control. Examples of such illnesses include neurological problems, cardiovascular diseases, cancer, AIDS, arthritis, bronchial asthma and diabetes. The escalating utilization of herbs is mirrored in their burgeoning trade: the current worldwide herbal industry, valued at around US\$62 billion, is expanding at an annual rate of 5% and may reach \$5 trillion by 2050. India's part in total commerce is about 2%, in stark contrast to our neighbouring country, China, which commands a substantial 33% stake. We export around Rs. 300 crores worth of herbal products from our yearly output, while local trade amounts to Rs. 4000 crores. The precise proportion of dry zones in India is unknown, however it is thought to be between 20% and 25%.

The arid region of Rajasthan is endowed with 628 species over 352 genera and 87 families. Among them, 116 species from 99 genera and 52 families are significant for their medicinal properties and are used as home remedies in traditional systems. Seventeen species are economically exploited, while twenty-eight species are components of Ayurvedic and Unani formulations. The majority of these species are gathered from natural ecosystems, fallow fields, field boundaries and wastelands. Further research indicates that among the 19 species most often used in pharmaceutical formulations, these also dominate the export market. Thirteen originate from arid and semiarid regions. Furthermore, several medicinal plants are optimally derived from the dry and semi-arid regions of Rajasthan, owing to the unique agro-climatic conditions there. The knowledge on these plants, including their occurrence, biology, applications and both raw and processed commercial products, is either fragmented, limited, or often unavailable.

Approximately seven percent of India's tribal population resides in Rajasthan. Rajasthan has significant cultural variety and biodiversity. The herbaceous vegetation on the slopes is abundant during the rainy season and mostly consists of little plants. In Rajasthan, 80% of the population lives in rural regions and lacks the financial means to purchase expensive medication. They rely on the surrounding flora and use it well for their therapeutic requirements. A significant variety of medicinally valuable tree species exists in the Aravalli hill range and other regions, including the inhospitable North-West Rajasthan. A floristic investigation identified 61 ethnomedicinal plant species from 38 families in the Aravalli hills of the Mewar area of Rajasthan.

The tribes reliant on forest resources are the true stewards that preserve medicinal plants to this day. Accelerated deforestation resulting from excessive harvesting and exploitative commerce of medicinal plants has markedly diminished the availability of these plants in the arid and semi-arid regions of Rajasthan. Typically, indigenous communities possess a profound understanding of the therapeutic attributes of the flora in their environment, especially concerning their health. Kheep (*Leptadenia pyrotechnica*) is a commonly found plant in western Rajasthan. It is

normally used as therapeutic remedy. Currently, natural products and herbal remedies are advocated for the management of diabetes. More than 50 plant species with antidiabetic properties are found in the dry region of Rajasthan. In the Dang area of Rajasthan, 36 plant species are used as cooling agents during the warm months. A conservation approach that employs in-situ methods is essential for sustainable development.

In parallel, aquatic plants represent another important component of biodiversity, comprising an ecologically diverse group that includes several taxonomic categories and thrives either partially or wholly submerged in freshwater and marine environments. Their ecological and medicinal significance further underscores the need for integrated conservation efforts across both terrestrial and aquatic ecosystems. This includes floating, submerged and emergent vegetation, in addition to mangroves, marshes and swamps. Aquatic macrophytes have garnered significant interest in recent decades as reservoirs of chemical substances having medicinal characteristics. Their photosynthetic processes in aquatic environments provide distinctive secondary metabolites that serve as chemical defenses against diseases and herbivores.

Numerous indigenous healing systems use aquatic plants to address various human illnesses. Members of the Nymphaeaceae family have historically been used in Ayurveda, Chinese and North American medicine as sedatives, astringents and remedies for diarrhea, dysentery, dysmenorrhea and gonorrhea. *Trapa natans* is used for rheumatism and dermatological conditions, whilst *Ceratophyllum demersum* serves as a diuretic and antidote for toxins in Indian traditional medicine.

Recent research has substantiated several conventional applications of these aquatic ethnomedicinal plants by scientific examination of their phytochemistry and pharmacology. The aquatic environment complicates the gathering of aquatic plants relative to terrestrial species. Their delicate ecosystem and precarious conservation status need meticulous recording and preservation methods. Aquatic floras globally are concurrently confronting problems from human activities such as wetland drainage, pollution, eutrophication and overharvesting. This highlights the need to document their traditional medical use before the priceless knowledge and the plant resources are lost. Local populations can significantly contribute to sustainable harvesting and provide insights for contemporary therapeutic development from aquatic plants (Meena 2015).

IV. CONCLUSION

The biodiversity of algal and aquatic plant species in India reflects the country's vast ecological heterogeneity and its rich aquatic ecosystems. This review highlights that, despite being a largely arid region, Rajasthan supports diverse and ecologically significant algal and aquatic plant communities, especially in its seasonal and perennial freshwater bodies. These organisms not only contribute to primary productivity and nutrient cycling but also play a critical role in maintaining water quality and supporting aquatic life. However, increasing anthropogenic pressures, pollution and climate change are posing serious threats to the sustainability of these ecosystems. In Rajasthan, where water bodies are already under stress due to limited rainfall and overexploitation, the conservation of aquatic biodiversity requires urgent attention. There is a clear need for systematic documentation, continuous monitoring and the implementation of region-specific conservation strategies.

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