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A Systematic Review on *Ceratophyllum Demersum L.* Found in Loktak Lake, Manipur, India

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Abstract

Ceratophylllum demersum L., commonly known as Coontail or Rigid Hornwort, is a rootless, free-floating aquatic macrophyte that is cosmopolitan in distribution. This species holds a dominant ecological niche and its diverse potentials in Loktak Lake, the largest freshwater lake in Northeast India and a Ramsar-designated wetland. This review is done based on published literature on the taxonomy, morphology, ecophysiology, distribution, allelopathic properties, and phytoremediation potential of C. demersum in the broader context of global literature. The present study reviews the ecology, distribution and significance of C. demersum. This rootless, submerged macrophyte has undergone significant expansion across the lake as a result of eutrophication and hydrological alteration following the construction of Ithai Barrage and nutrient loads from anthropogenic activities. However, this species exhibits a broad ecophysiological tolerance, demonstrate considerably phytoremediation potential, absorbing excess nitrogen, phosphorous and heavy metals from the water column. The dual nature of this species poses both challenges and opportunities for wetland management. The review identifies key knowledge gaps and proposes a long-term monitoring to restore the ecological balance of this globally significant wetland and for sustainable management of C. demersum L. This review underscores that sustainable management of C. demersum cannot be achieved through species-level interventions alone; it requires holistic watershed governance, restoration of natural hydrological regimes, and inclusive community participation.

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1. INTRODUCTION

Loktak Lake (24°25′–24°42′N; 93°46′–93°55′E) lies in the Bishnupur district of Manipur, Northeastern India, at an elevation of approximately 768 m above mean sea level. It constitutes the largest natural freshwater lake in Northeastern India, listed under Ramsar Wetland of International Importance in 1990 [38,16]. Loktak is part of the Keibul Lamjao National Park, the world's only floating national park, the only natural habitat of the highly endangered brow–antlered deer, Sangai (Rucervus eldi eldi) and numerous fish, bird, and invertebrate species [26,32].

The lake has a unique ecological feature, i.e., the floating biomass locally known as Phumdi, a buoyant matrix of intertwined roots, decomposing organic matter, and soil that covers an estimated 40% of the lake surface during summer [1]. The Keibul Lamjao National Park is the only national floating park that lies in the southern part of the lake. Over the past four decades, however, the ecological integrity of Loktak has been compromised by siltation, nutrient enrichment due to agricultural runoff, urban effluents, population pressure, and hydrological alterations due to the Ithai Barrage constructed in 1983 for the Loktak Hydroelectric Project [7,11]. These disturbances have led to the proliferation of aquatic macrophytes, particularly the submerged species Ceratophyllum demersum L. (Ceratophyllaceae), locally known as “Charang”. It is also commonly known as coontail, hornwort, or rigid hornwort.C. demersum is a rootless, freely floating or weakly anchored macrophyte renowned for its rapid vegetative growth and cosmopolitan in nature, with a wide range of physicochemical conditions, and strong allelopathic activity against phytoplankton [21,27]. In eutrophied freshwater bodies, C. Demersum forms dense monospecific mats that impede water circulation, reduce light penetration, deplete dissolved oxygen at night, and competitively exclude native aquatic flora and fauna [39,29]

Despite the well-documented global ecology of C. demersum, its specific role, distribution dynamics, and management implications within the unique phumdi-dominated ecosystem of Loktak Lake remain insufficiently synthesised. This systematic literature review aims to: (i) study the taxonomic and morphological characteristics of C. demersum; (ii) review its ecophysiological adaptations relevant to Loktak Lake; (iii) examine documented evidence of its distribution and ecological impacts in the lake, and (iv) assess its allelopathic and phytoremediation properties. By bridging global knowledge of C. demersum with the specific socio-ecological context of Loktak, the review seeks to inform policy decisions for sustainable wetland management.

2. METHODOLOGY

Using the following electronic databases: Web of Science, Scopus, PubMed, Google Scholar, and a regional publication repository. The primary search combined terms: ("Ceratophyllum demersum") AND ("Loktak Lake" OR "Manipur" OR "Northeast India" OR "freshwater wetland" OR "phumdi"). Broader terms for secondary search: ("macrophyte ecology" OR "submerged macrophyte" OR "allelopathy" OR "phytoremediation") to search for studies applicable to Loktak conditions. A field visit was conducted at the study to understand the environment and ecological characteristics seasonally. Field records were collected, and a survey was taken among the people residing near the lake about the study site and the plant to be studied.

3. RESULTS

3.1 Taxonomy and Morphological Characteristics of Ceratophyllum demersum

Ceratophyllum demersum L. belongs to the order Ceratophyllales under the family Ceratophyllaceae. The genus name is derived from the Greek “cerato”(horn) and “phylum” (leaf), in reference to the horn-like, forked leaf segments. According to the APG IV system, Ceratophyllaceae is placed in the order Ceratophyllales. This species is commonly known by many names, i.e., rigid hornwort, coontail, coon's tail, and common hornwort.

Scientific Classification
Kingdom – Plantae
Phyllum – Spermatophyta
Sub Phylum – Angiospermae
Class – Dicotyledonae
Order – Nymphaeales
Family – Ceratophyllaceae
Genus – Ceratophyllum
Species - demersum

Morphologically, C. demersum is characterised by dichotomously branched, brittle, dark-green stems that can reach 1–3 m in length. Leaves are dark green, with whorls of 5-12, sessile, with thickened bases, rigid, and toothed segments with minute serrations. The plant is entirely rootless; instead, modified into stems (rhizoids) that anchor weakly in sediment, or the plant floats freely in the water column [22]. Flowers are small and inconspicuous, unisexual, and sessile in leafy axils.It is a hydrophilic pollinated plant. The fruits are black ellipsoid achenes 4 to 5 mm long with three basal spines, one at the terminal and two laterals [22]. In Loktak Lake, field surveys have recorded the typical form and a denser, more branched dichotomously forked toothed type, i.e., Ceratophyllum demersum L. ecotype in and around the lake areas [4]

3.2 Ecophysiology and Distribution in Loktak Lake

C. demersum can colonise in highly eutrophic and disturbed water bodies as it is euryhaline, eurythermic and exceptionally tolerant of turbidity, hypoxia, and wide ranges of pH (5.0–10.0) and temperature (5–30°C) [21,12]. It is also reported to be found in the Kongba River in shallow and slow- flowing areas. In Loktak Lake, the macrophyte surveys conducted during the period 1980–2020 in Loktak Lake, documented a progressive expansion of C. demersum from localised patches near Phumdi margins to extensive, near-continuous beds across the southern and central basins of the lake [31,14]. Singh and Meetei (2005) recorded C. demersum as one of the dominant submerged macrophytes after Hydrilla verticillata and Potamogeton pectinatus [31]. The recent remote-sensing analysis by Sharma et al. (2019) estimated that submerged

macrophytes, with C. demersum, occupy approximately 28–34% of the open-water zone during the post-monsoon season [30]

3.3 Significances of Ceratophyllum demersum L.

C. demersum supports the piscivore species, and the C. demersum bed acts as a nursery habitat for juvenile fishes. Singha and Dey (2018) recorded 22 fish species associated with C. demersum beds in Loktak, including economically important species such as Osteobrama belangeri and Channa striata [35]. The biomass of C. demersum beneath phumdis accelerates organic matter accumulation, which facilitates phumdi grounding [15]. The exudates of C. demersum include polyphenols, particularly luteolin, apigenin, and their glycosides, as well as fatty acids and terpenoids, that inhibit cyanobacterial and green algal growth through disruption of photosystem II, cell membrane integrity, and enzyme activity [8,20]. Studies have shown that C. demersum has been an effective phytoremediator of excess nutrients, heavy metals, and certain organic pollutants from aquatic systems. Experiments by Dhote and Dixit (2009) reported that C. demersum could remove up to 61.4% of total nitrogen and 66.0% of total phosphorus from eutrophic water within 30 days. Devi et al. (2012), working in Loktak Lake sediment extracts, found elevated levels of Pb, Cr, and Ni that are from the agricultural inputs and upstream industrial activity, suggesting a potential role for C. demersum as an in-situ bioindicator and phytoextractor in contaminated zones [5]

4. DISCUSSION

The literature reviewed reveals Ceratophyllum demersum to be one of the most thoroughly studied submerged aquatic macrophytes, particularly in the domains of allelopathy and phytoremediation, yet its role in relevance to Loktak Lake remains insignificant. The ecological context of the lake suggests that this plant may serve an important role, but it remains undocumented.C. demersum is as a species with a dualistic ecological role. It provides essential ecosystem services, including fish nursery habitat, allelopathic properties, and nutrient retention capacity.C. demersum could be used for integrated lake restoration programs for Loktak Lake. Phytoremediation using C.demersum mats in the target highly eutrophic and polluted zones of high nutrient and metal loading areas, such as river inflow points, agricultural runoff areas, etc. The allelopathic properties of the species suppressed the cyanobacterial blooms. On the other hand, the unchecked proliferation under eutrophic conditions generates hypoxic events, alters fish community structure, and accelerates Phumdi grounding. Dense monospecific beds of the species can exclude other plant species and reduce dissolved oxygen from the decomposition of the large biomass. It could be a transitional ecological shift rather than restoration. Management of C. demersum, therefore, cannot be kept apart from the broader hydrological context of the lake. Although the phytoremediation capacity of C. demersum is well-established, it poses a significant practical challenge. As improper disposal or composting of harvested biomass could return sequestered pollutants to the environment [28], C demersum can be a potentially cost-effective management option for the nutrient removal of the targeted inlets of the lake areas if properly managed, the harvested biomass [6,37]

This review identifies several knowledge gaps. The genetic diversity of C. demersum populations within Loktak and their connectivity to populations in upstream river systems remain undone.No study has quantified the net carbon budget of C. demersum in Loktak under current eutrophication conditions, which is important for understanding its contribution to greenhouse gas. Effective management of C. demersum requires an integrated, multiscale approach addressing both nutrient enrichment, altered hydrology and land-use change operations. Participatory macrophyte mapping and harvest schemes could simultaneously address livelihood needs and ecological restoration goals. Crucially, any management intervention must be guided by adaptive management principles, with regular monitoring of the changing nature of the lake ecosystem and the high sensitivity of phumdi integrity to disturbance.

5. CONCLUSION

C. demersum is a confirmed component of the macrophytic flora of Loktak Lake, classified under the Ceratophyllaceae, documented across multiple ecological surveys spanning several decades. Its expansion, driven by decades of eutrophication and hydrological modification, has reshaped the submerged macrophyte community, altered nutrient and oxygen dynamics and created cascading effects on fish communities, phumdis, and human livelihoods. Its rootless, free-floating growth strategy, combined with high shade tolerance, positions it as a potential dominant species under the eutrophied and turbid conditions increasingly characteristic of the lake. This review underscores that sustainable management of C. demersum cannot be achieved through species-level interventions alone; it requires holistic watershed governance, restoration of natural hydrological regimes, and inclusive community participation. Future research priorities should include long-term biomass monitoring using remote sensing; quantification of carbon and nutrient fluxes associated with C. demersum dynamics, systematic quantitative surveys of C. demersum distribution and biomass across seasonal cycles in Loktak Lake, and molecular and physiological studies of C. demersum stress responses to Loktak-specific pollutant profiles. The unique ecological heritage of Loktak Lake and its Phumdis, the Sangai, and its fishing communities warrants urgent, science-informed action to restore and sustain this irreplaceable Ramsar wetland.

Conflict of Interest

The authors declare that they have no conflict of interest.

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