



## Research article

## Taxonomic revision and new locational report of *Limnophila indica* (L.) Druce: A species becoming rare by the invasion of aquatic macrophytes

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**Abstract:** The Indian marshweed, “*Limnophila indica*” had not given much attention as valued in traditional medicinal practices in India. This work revised the lacking of taxonomic characters and the population status of this species which investigated from four major wetlands, (*i.e.*, Chilika lagoon, Ansupa lake, Kanjia lake and Deras dam) of Odisha state, India. In field condition, the plant can be easily identified from other close relative species by their heterophilic leaf (*i.e.*, polymerous submerged leaf and whorled or opposite sessile aerial dichotomous leaves), pedicellate flowers arranged in spikes, tubular or funnel-shaped pubescent petals with a bluish-violet tinge, didynamous stamen and fruits of ellipsoidal to globose capsule with numerous seed. Past studies reported it as a common weed in rice fields but lacked its distribution and existing population in any wetland where it had been recorded. Our field observation recorded the species is of rare and under threat for its existence in major wetlands of Odisha. The distribution was strongly contagious and species abundance was rare. The major cause of population decline was found to be habitat loss and invasion of other aggressive aquatic macrophytes such as *Salvinia molesta*, *Eichhornia crassipes*, *Typha angustifolia*, *Phragmites karka*, *Pistia stratiotes*, *Ipomoea aquatica* and few others. The immense medicinal potential of the plant reported in past and recent studies emphasizing to take necessary measures for its conservation in natural aquatic ecosystems of Odisha and India.

**Keywords:** *Limnophila* - Taxonomy - Macrophyte invasion - Habitat loss - Conservation.

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### INTRODUCTION

Aquatic plants play a major role in wetland functioning. They are the source of many indigenous plant products for local stakeholders. Increasing anthropogenic activity and environmental change affecting the proper functioning of wetlands throughout the globe. In existing scenario, many wetlands are experiencing a great loss in terms of their water spread area and change of once existing diverse species of flora and fauna. Wetland floras are unique in terms of their adaptation to various degrees of water level and availability of edaphic factors. The genus ‘*Limnophila*’ is peculiar that all the species that belongs to the genus are comparatively small aquatic or semi-aquatic emergent herbs inhabiting marshes, riversides, forest paths or similar wet places (Philcox 1970). The number of reported and existing species under the genus is a matter of contention as differently estimated. Available literature showed that the genus bears 35 (Philcox 1970), 36 (Rutishaue 1999, Tucker & DeBaggio 2009, Les 2018) or 40 (Shi 1998) species. They are more common in tropical and subtropical regions of the Old World where the genus is native (Les 2018).

The name of the genus probably derived from Greek word *limne* (“pool”) and *philos* (“loving”) (Tucker & DeBaggio 2009). The plants are most commonly known as Asian marsh weed. About 13 species are truly aquatic and bear finely divided submerged leaves (Cook 1996, Rutishaue 1999). Aquatic species (*e.g.*, *Limnophila*

*heterophylla* (Roxb.) Benth., *Limnophila indica* (L.) Druce and *Limnophila sessiliflora* (Vahl) Blume) are heterophyllous (Rutishauser 1999). This is a distinctive feature of many species of the genus. The plants of genus 'Limnophila' are widely distributed throughout India, and occupy a significant position in traditional systems of medicine (Brahmachari 2014). In India, this genus is represented by 22 species of which 9 species occur in South India (Hooker 1885, Gamble 1935).

This particular study was conducted to find out the population status of *Limnophila indica* which had been considered as a common wetland species in the Indian subcontinent. The taxonomic study and distribution of species belongs to the genus is very rare and available literature only listed their presence if found. Due to morphological similarity with other species of the genus many times they got wrongly identified. The species is commonly known as Indian marshweed (Lansdown 2014). Somatic chromosome number of *L. indica* is  $2n=34$  (Chandran & Bhavanandan 1986).

The plant is a heterophilic wetland macrophyte. It grows in still or running water habitats where the light levels are high (Les 2018). The species bears soft underwater and emergent erect stem. At the Juvenile stage, it occurs as a submerge species having polymerous leaves. A few polymerous whorls may show transitional leaves (Mohan Ram & Rao 1982). The aerial leaves are toothed and lanceolate. Intermediate leaf types had been reported to occur in the transitional zone and flowers are born only on aerial shoots (Mohan Ram & Rao 1982). This taxon is extremely variable in its vegetative characters (Naskar 1990) which creates difficulty in field identification. *Limnophila indica* is more commonly distributed in Australia and East Asia (Ito & Barford 2014).

Odisha is a coastal state of India and holds diverse ecosystems of both terrestrial and aquatic types. Different types of major aquatic ecosystems of the state include marine (*i.e.*, Bay of Bengal), estuarine and mangrove (Bhitarkanika and Mahanadi delta), brackish water (*i.e.*, Chilika lagoon) and freshwater wetlands (Ansupa lake, Kanjia lake, Hirakud dam, Rengali dam, Daha lake, Kuanria wetland, etc.). The study of aquatic flora, their ecological role and uses are inadequately studied in the state. Major wetlands of the state are under strong infestation by few invasive macrophytes. Extensive growth of these invasive weeds along with anthropogenic factors changing the natural habitat of wetlands in Odisha state. These factors are also strongly affecting the existence of native species.

The taxonomic work on flora of Odisha by Hains (1921–25) and Saxena & Brahamam (1994–96) had identified occurrence of nine species of the genus '*Limnophila*' from Odisha. These species were *Limnophila aromatica* (L.) Merr., *L. rapens* (Benth.) Benth., *L. connata* (Buch.-Ham. ex D. Don) Hand.-Mazz., *L. rugosa* (Roth) Merr., *L. aquatica* (Roxb.) Alston, *L. indica* (L.) Druce, *L. sessiliflora* (Vahl) Blume, *L. chinensis* (Osbeck) Merr. and *L. heterophylla* (Roxb.) Benth. Recently, 3 species of *Limnophila* (*i.e.*, *L. aquatica* (Roxb.) Alston, *L. chinensis* (Osbeck) Merr. and *L. indica* (L.) Druce) had been recorded from 'Balasore', a coastal district of the state (Sujana *et al.* 2015). Similarly, four species of *Limnophila* (*i.e.*, *L. aquatica* (Roxb.) Alston, *L. heterophylla* (Roxb.) Benth., *L. indica* (L.) Druce and *L. sessiliflora* (Vahl) Blume) had been reported to occur as annual species in Ansupa lake (Panda *et al.* 2018). But, these studies lacked precise taxonomic enumeration, existing population status, associated flora, habitat impact and whether conservation is required.

This particular study, investigated regarding taxonomic characterization, distribution and population status of the indigenous species, *L. indica* from major inland and coastal wetlands of Odisha state, India. The phytomedicinal uses of this unvalued species of Odisha state were reviewed which will help to give valuable attention towards need of conservation of this indigenous flora in studied natural wetlands.

## MATERIALS AND METHODS

### Study area

Four major wetlands of Odisha state (*i.e.*, Chilika lagoon, Ansupa lake, Kanjia lake and Deras dam (a tourist destination within Chandaka-Dampara Wildlife Sanctuary) were investigated to find out distribution and existing population of *L. indica*, an indigenous species which understudied considering its weed nature (Fig. 1).

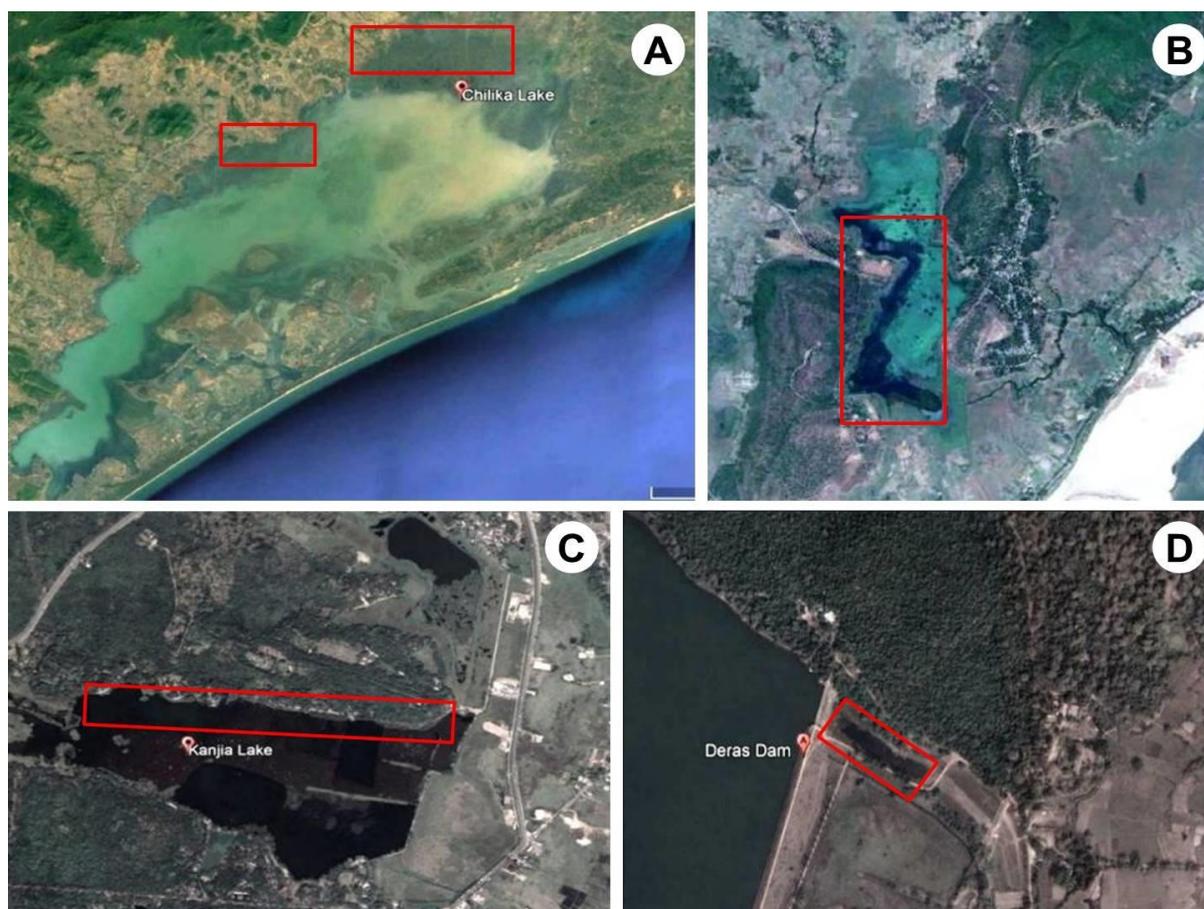
Chilika is a brackish water lagoon (commonly known as Chilika lake) but northern sector of it provides fresh water habitat and supports most diverse freshwater macrophytes (Fig. 1A). Presently, *Limnophila indica* only recorded from this particular area. The lagoon is a hotspot of aquatic bio-diversity and home to some threatened species. The area under it varies between 900 km<sup>2</sup> during summer to 1200 km<sup>2</sup> in monsoon and situated between latitude 19° 28' to 19° 54' N and longitudes 85° 05' to 85° 38' E. Chilika lagoon is the paradise for migratory birds in winter and hosts the largest population of Irrawaddy dolphins in Asia. Due to estuarine and brackish water habitat, it is a highly productive ecosystem and rich in fishery resources. After a recent update it had been listed that the lagoon hosts seven hundred ninety species of angiosperms in and its immediate neighbourhood

(Kar *et al.* 2016).

Ansupa lake is the largest freshwater lake of the State, situated between latitude 20° 26' 21" to 20° 28' 52" N and 85° 36' 25" to 85° 36' 0" E longitude on the riverbank of Mahanadi (Fig. 1B). The area of the lake varies between 375–385 acres at different seasons. A recent study reported the occurrence of 244 macrophytes from the lake (Panda *et al.* 2018).

Kanjia lake is a small inland freshwater wetland, situated inside Nandankanan Wildlife Sanctuary in Khorda district between latitude 20° 23' to 20° 24' N and 85° 49' to 85° 48' E longitude (Fig. 1C). The water spread area of the wetland is about 4.37 km<sup>2</sup>. Field inspection showed that the wetland is strongly infested by few aggressive and fast-growing aquatic macrophytes.

The fourth location, the Deras dam is situated inside Chandaka-Dampara Wildlife Sanctuary between latitude 20° 18' to 20° 19' N and 85° 41' to 85° 40' E longitude. The dam provides irrigation for continuous agriculture (rice and vegetables) by local farmers. Most of the population of *L. indica* is confined to a small area (~600 m<sup>2</sup>) at the water exit point from the dam (Fig. 1D).



**Figure 1.** Studied wetlands of Odisha and location of sampling area marked in box: **A**, Chilika lagoon; **B**, Ansupa lake; **C**, Kanjia lake; **D**, Deras dam. [Source: Google earth]

#### Field data collection and taxonomic study

The work is the result of multi-seasonal (summer, monsoon, winter) field investigation from the calendar year 2016 to 2018 to the mentioned wetlands of Odisha. Existence and distribution of *Limnophila indica* was noted from field inspection. Morphometric taxonomic studies were carried using field-based plants. Digital photographs were taken showing different taxonomic characters for better identification and for use in future studies. Numerical strength or existing populations were counted from the occurred sites. Phenology and flower pollinators were recorded *in-situ* from different locations. Associated floras were recorded infield. Habitat shrinkage and loss due to invasion of invasive species were also noted. Plant specimens were collected for further taxonomic study and preservation in herbarium.

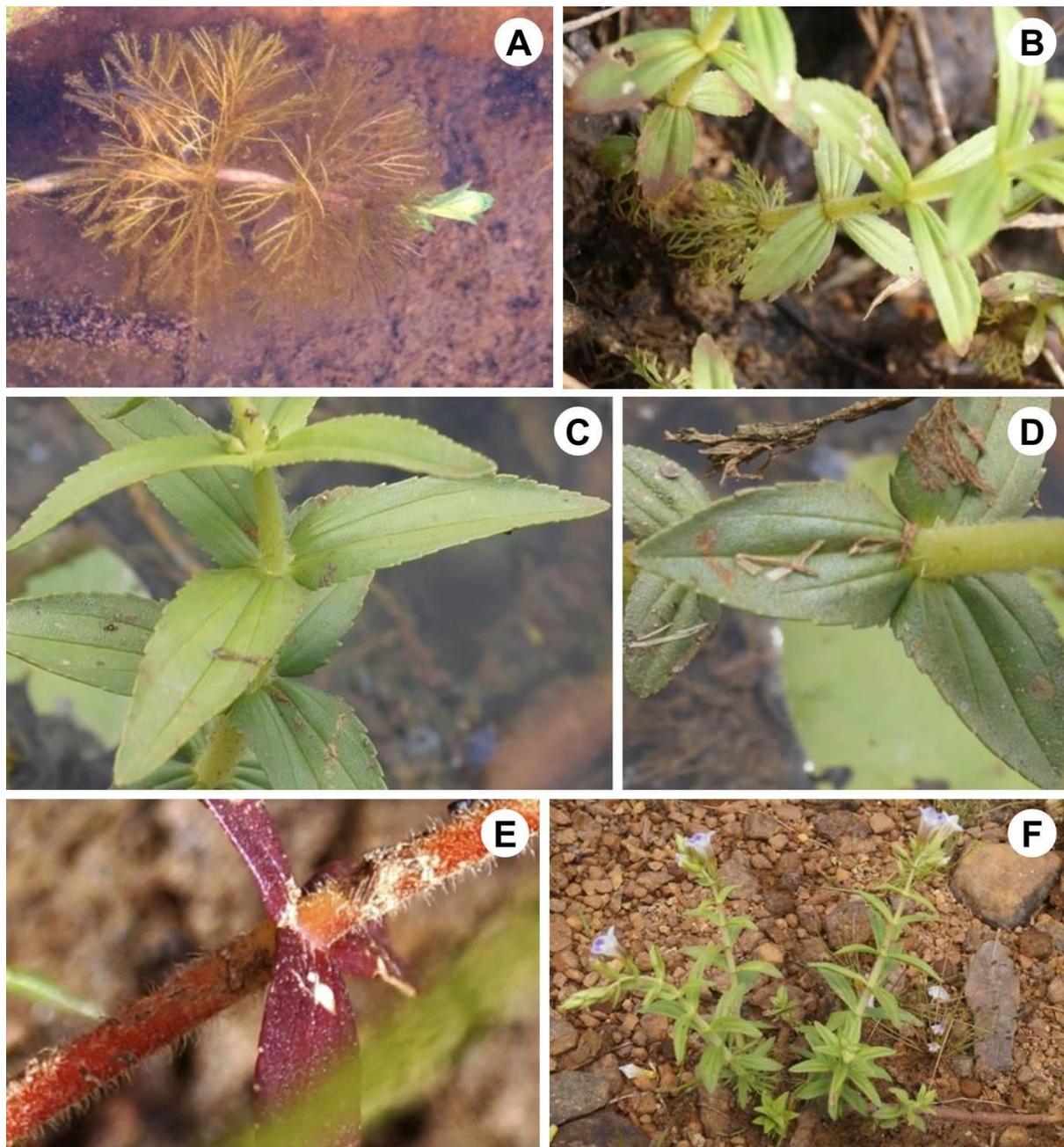
## RESULTS AND DISCUSSIONS

The plants were found to grow on slow running freshwater wetlands and shallow water bodies. More prefer on loamy or less clay wetland habitats. Shore areas were mostly inhabited and can withstand water depth upto 1

meter. The size of plant and flower parts strongly depends on water depth and habitat conditions. The species is an annual aquatic macrophyte. The occurrence of Juveniles or germination starts after the arrival of monsoon in India. Plants show their first appearance during August, grow as submerged macrophytes for 45–60 days and then start bearing flowers towards December, continues upto March. Fruit appears from January to April. Plants die out in May. The phenology slightly varies between sites and much depends on water availability. Lack of water initiates early flowering.

This study found that the populations of *Limnophila indica* were small and rare from the wetlands under consideration. The species was altogether absent from Kanjia lake. We recorded only 30 individual from Ansupa lake and about 145 from land water transitional zone at northern sector of Chilika lagoon. The above wetlands are much larger and host a diverse form of aquatic flora and fauna of the state but hosted very limited population of *L. indica*. The majority of the individuals were recorded from a small area of about 600 m<sup>2</sup> close to the Deras dam (Fig. 1D). We counted the existence of about 250 individuals from this location.

#### Taxonomic treatment & plant description



**Figure 2.** Vegetative characters and habit of *Limnophila indica* (L.) Druce.: **A**, Plant showing both submerged polymerous and aerial whorled dicotyledonous leaves; **B**, Lower transitional dissected with aerial leaves; **C & D**, Whorled trimerous sessile aerial leaf with three prominent veins; **E**, Cylindrical pubescent and soft aerial stem; **F**, A branched complete plant from distance with upper opposite leaves.

***Limnophila indica* (L.) Druce**, Bot. Exch. Club Soc. Brit. Islets 3:420.1914; Philcox, Kew Bull. 24:115.1970; Cramer in Dassan. & Fosberg, Rev. Handb. Fl. Ceylon 3:432.1981. [Fig. 2]

*Hottonia indica* L., Syst. Nat. ed.10, 919.1759. *Cyrella aquatica* Roxb., Pl. Cor. t. 189. 1798. *Limnophila gratioides* R.Br., Prodr. 442. 1810; Hook. f. in Hook. f. Fl. Brit India. 4:271. 1884; Haines, Bot. Bihar & Orissa. 2:628(658). 1922; Gamble, Fl. Presi. Madras 2:952(668). 1923. *Limnophila racemosa* Bentham, Scroph. Ind. 26. 1835; Wight, Ic. t. 861. 1844-1845; Gamble, 952(668). 1923.

An annual aquatic herb, partially submerged, upto 50 cm in height (Saxena & Brahaman 1994–96, Shi 1998). Stems erect and rarely branched, cylindrical, weak and soft, pubescent, nodes and internodes prominent, rooting occurs from lower nodes (Naskar 1990, Shi 1998) (Fig. 2B, F). Leaves dimorphic, submerged leaves in whorls and pinnately dissected, looks like small root, upto 50 in number, emergent leaves are sessile, occur in whorled (*i.e.*, 3 leaves) or opposite, serrate, leaf 3–5 ribbed from base and 3 veins prominent (Hooker 1885, Saxena & Brahaman 1994–96, Shi 1998) (Fig. 2A–D). Flowers either in raceme (common) or small spikes, pedicellate, pedicel ranges from 0.5–1.2 cm (Saxena & Brahaman 1994–96) (Fig. 3A, C). Bracteoles linear. Calyx not striate. Sepals tubular, 5 lobed, 0.5–1.0 cm, acute or acuminate, persistent (Saxena & Brahaman 1994–96) (Fig. 3B–C). Petals tubular or funnel shaped, hair present, whitish, with blush-violet tinge, growing upto 2.5 cm on branched spikes, 5 lobed, 2-lipped; upper lip outside in bud, entire or 2-lobed; lower lip (abaxial lip) 3 lobed, erect or spreading (Naskar 1990) (Fig. 3B–E). Stamen 4, didynamous, adaxial pair shorter or rarely absent; anthers free, usually divergent. Ovary glabrous; style capillary, deflexed at tip; stigma 2-lipped. Fruit is a loculicidal, ellipsoidal to globose capsule with persistent striated calyx (Naskar 1990, Saxena & Brahaman 1994-96, Shi 1998) (Fig. 3F–H). Seeds truncate, numerous (Naskar 1990).

**Pollination:** The reproductive biology of this genus is poorly known and pollination takes place by wind and insects (Les 2018). We recorded bugs, moths and bees as important insect pollinators of this plant (Fig. 3I–J).

**Associated species:** The species showed clumping pattern of occurrence. Some species which we had recorded to coexist were *Schoenoplectus articulatus* (L.) Palla, *Ottelia alismoides* (L.) Pers., *Vallisneria spiralis* L., *Utricularia aurea* Lour., *Nymphoides hydrophylla* (Lour.) Kuntze, *Aponogeton natans* (L.) Engl. & K. Krause, *Potamogeton nodosus* Poir., *Scoparia dulcis* L., *Phyla nodiflora* (L.) Greene (Fig. 4C–I).

**Species distribution:** The species shows widespread distribution. In India, it is more common in coastal states. The detailed country-wise distribution (Rahman 2006, Lansdown 2014, Les 2018); countries in which it got introduced and occurrence in states of India (Lansdown 2014, Prajeesh *et al.* 2014, Rahangdale & Rahangdale 2017, Jyothi & Sureshkumar 2018, Kumar *et al.* 2019) had given (Table 1).

**Table 1.** Distribution (Global and in India) of *Limnophila indica* (L.) Druce.

Native countries	Introduced	In India
Australia, Cambodia, China, India, Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Oceania, Pakistan, Sri Lanka, Papua New Guinea; Philippines, Thailand, Taiwan, Vietnam and Bangladesh	Botswana; Madagascar; South Africa; United States (Florida, Louisiana, Texas); Zimbabwe	Madhya Pradesh, Karnataka, Kerala, Maharastra, Jammu-Kashmir, Goa, Assam, Manipur, Odisha, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal; Uttarakhand

**Uses:** The plant is eaten as a leafy vegetable (Lansdown 2014). The medicinal properties of the species are well documented in traditional practices. Smearing of the plant with coconut is applied in elephantiasis (Naskar 1990, Ghosh 2005). Juice of the plant is used to cure dysentery in addition with ginger, cumin and other aromatics. Used to prevent gas formation in the gastrointestinal tract. The plant is used by the local tribal people as carminative and antiseptic (Lansdown 2014, Suthari *et al.* 2018).

*Limnophila indica* (L.) Druce has appeared to be a rich source of flavonoids. The plant extract has been tested to act as a strong anti-microbial agent (Brahmachari *et al.* 2013).

In India, the Lodha people use a paste of the plant made with *Pongamia pinnata* (L.) Pierre. seed oil for the treatment of elephantiasis. The Santal people apply fresh juice of the plant with ginger as an anthelmintic (Ahmed *et al.* 2009).

The literature showed that different parts of the plant extract have actions of anti-dyspepsia, anti-dysentery, anthelmintic, anti-septic, anti-filariasis, carminative, anti-shigella, antacid, anti-microbial, hepato-protective and cytotoxic properties (Brahmachari 2014, Chakraborty *et al.* 2016). Many species of ‘*Limnophila*’ especially the submerged ones have potential value as the aquarium plants and in water gardening (Greg & Speichert 2004).

*Limnophila* has been considered for use as a water purifying species, to incorporate in the treatment of industrial wastewater effluents (Les 2018). A recent study had identified the presence of thirty-five phytochemical compounds from oil extract of aerial parts (Kumar *et al.* 2019). It is a plant having immense number chemicals of phytomedicinal values which needs further study and efficiency evaluation.

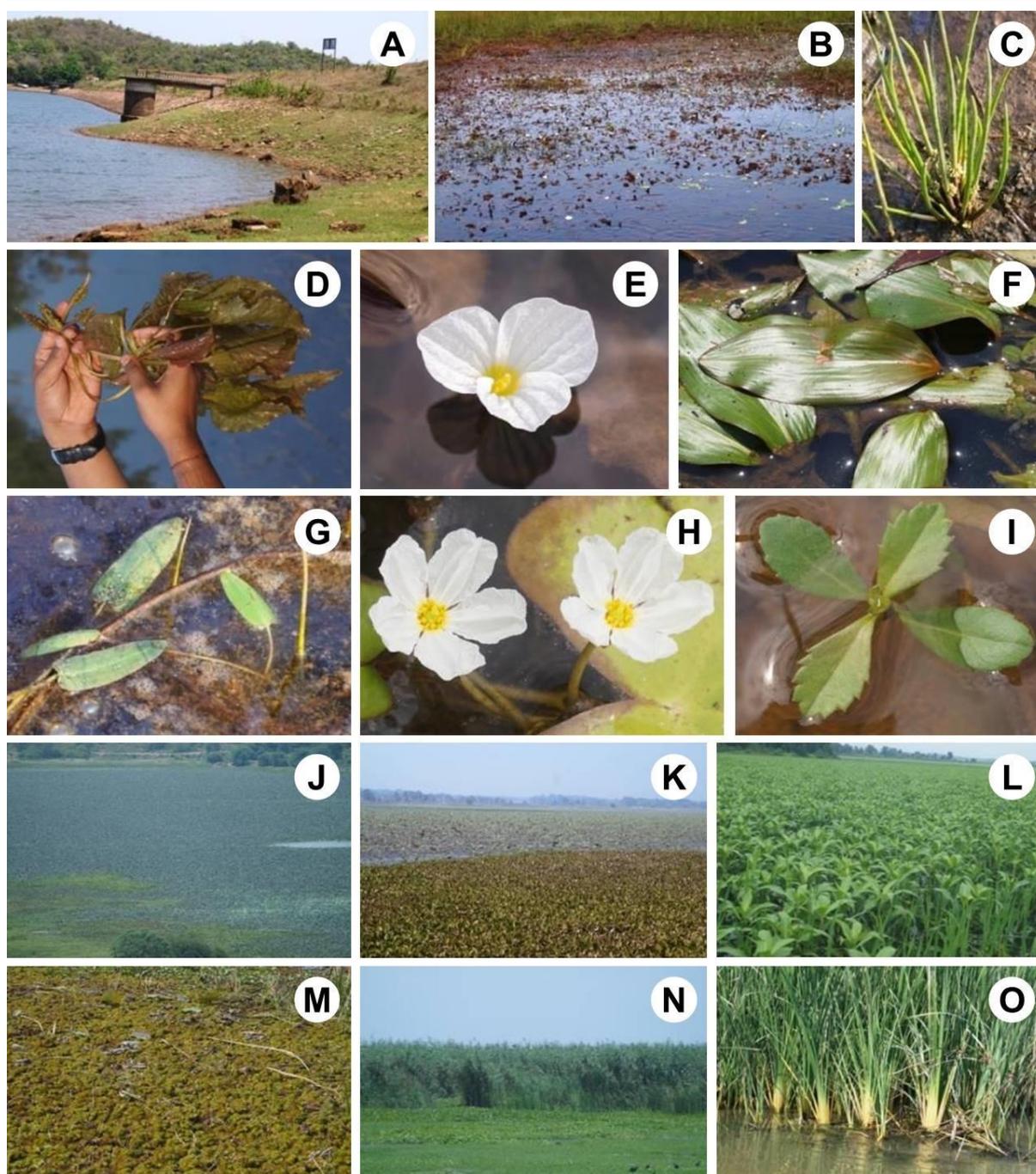


**Figure 3.** Floral and other related characters of *Limnophila indica* (L.) Druce: **A**, Flowers in raceme; **B & C**, Long acute tubular sepals and petals funnel shaped, outer surface of petals are violetly veined, prominent pedicilate flowers; **D & E**, Top view of flowers showing 5 lobed and 2-lipped petals, upper lip 2 lobed with blush-violet tinge, lower lip 3 lobed and lacks ting, inner surface hairy; **F**, A complete plant with leaf, flower and fruit; **G & H**, Capsular fruit with persistent calyx; **I & J**, Insect pollinators inside flower; **K**, Leaf variation; **L**, Plant size and colour variation in sandy and more terrestrial condition.

### THREATS AND CONSERVATION

It was in 2009, the loss of the species from Bangladesh was reported for the first time and the main cause of the decline was the loss of habitat (Ahmed *et al.* 2009). The juveniles are much exploited as an aquarium plant which affects the seed set, plant propagation and population stability.

Our study found a significant loss of habitat from the study areas. The existing populations were rare. This small herb at Deras site were under threat as the site is a tourist destination and much of the plant get



**Figure 4.** Associate flora and invasion of aquatic macrophytes in study sites: **A & B**, Deras dam site; **C**, *Schoenoplectus articulatus* (L.) Palla; **D & E**, *Ottelia alismoides* (L.) Pers.; **F**, *Potamogeton nodosus* Poir.; **G**, *Aponogeton natans* (L.) Engl.; **H**, *Nymphaoides hydrophylla* (Lour.) Kuntze; **I**, *Phyla nodiflora* (L.) Greene; **J–L**, Macrophyte (*Nelumbo nucifera* Gaertn., *Eichhornia crassipes* (Mart.) Solm-Laub.) invasion in Ansupa lake; **M**, Macrophyte (*Salvinia molesta* D.S. Mitch) invasion in Kanjia lake; **N & O**, Macrophyte (*Phragmites karka* (Retz.) Trin. ex Steud, *Eichhornia crassipes* (Mart.) Solm-Laub., *Typha angustifolia* L.) invasion in Chilika lagoon.

damaged unknowingly by visitors because of the colour attraction of flower. Plucking of flowers before reaching maturity or seed formation reducing the population size. Anthropogenic activities, siltation in water bodies and occupancy of wetlands by invasive aquatic macrophytes affecting the existence of this species in Chilika lagoon and Ansupa lake. The plant was completely absent in Kanjia lake due strong infestation of aquatic macrophyte like *Salvinia molesta* D.S. Mitchand, *Eichhornia crassipes* (Mart.) Solm-Laub. Other invasive species like, *Typha angustifolia* L., *Phragmites karka* (Retz.) Trin. ex Steud, *Pistia stratiotes* L., *Ipomoea aquatica* Forssk., *Ludwigia adscendens* (L.) H. Hara, *Nelumbo nucifera* Gaertn. and *Polygonum barbatum* L. along with the former two species affecting the existence of *Limnophila indica* (in Chilika lagoon and Ansupa lake (Fig. 3J–O)). Growths of these aggressive aquatic plants along the shallow water zone not allowing growth of *L. indica* and subsequently forcing it to become rare. The study reported that the seeds have

a low germination rate (Les 2018). This is another factor for the decrease of population size. Plant conservationists had not given focus to this species because it is considered as a weed in the rice field. Past studies also not emphasized its population status. But, we found that the plant is under strong pressure for extinction from natural wetlands of Odisha. Habitat protection is suggested to conserve the species in Bangladesh (Ahmed *et al.* 2009). In vitro regeneration of this plant showed success from various past and recent studies. Regenerating whole plant from in-vitro cultured root tips had shown positive result (Rao & Mohan Ram 1981). A recent study resulted that the plant can be tissue cultured using root tip sections that are floated on a 2% sucrose medium for 4 weeks (Les 2018).

We suggest that the germplasm need to be conserved for its unique phytochemical constituents which also need to be evaluated by modern techniques. Protecting natural habitat, removing the invasive macrophytes from wetland areas and through practicing in vitro propagation, the plant can be protected for its long term existence.

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## REFERENCES

- Ahmed ZU, Hassan MA, Begum ZNT, Khondker M, Kabir SMH, Ahmad M & Ahmed ATA (2009) *Encyclopaedia of flora and fauna of Bangladesh. Angiosperms: Dicotyledons (Ranunculaceae – Zygophyllaceae)*. Asiatic Society of Bangladesh, Dhaka.
- Brahmachari G (2014) *Limnophila* (Scrophulariaceae): Chemical and Pharmaceutical Aspects - An Update. *The Open Natural Products Journal* 7: 1–14.
- Brahmachari G, Mandal NC, Roy R, Ghosh R, Barman S, Sarkar S, Jash SK & Mondal S (2013) A new pentacyclitriterpene with potent antibacterial activity from *Limnophila indica* Linn. (Druce). *Fitoterapia* 90: 104–111.
- Chakraborty R, Mondal MS & Mukherjee SK (2016) Ethnobotanical information on some aquatic plants of South 24 Parganas, West Bengal. *Plant Science Today* 3(2): 109–114.
- Chandran R & Bhavanandan KV (1986) Cytological Investigation of the Family Scrophulariaceae I. *Limnophila* R. Br. *Cytologia* 51: 261–270.
- Cook CDK (1996) *Aquatic and Wetland plants of India*. Oxford University Press. Oxford.
- Gamble JS (1935) *Flora of the Presidency of Madras*. Second Reprinted Edition 1967. Vol. II. Botanical Survey of India, Calcutta.
- Ghosh SK (2005) *Illustrated aquatic and wetland plants in harmony with mankind*. Standard Literature, 76, Acharya Jagadish Chandra Bose Road, Kolkata, India.
- Greg & Speichert S (2004) *Encyclopedia of Water Garden Plants*. Timber Press. Portland, USA & Cambridge, UK.
- Hains HH (1921-25) *Botany of Bihar and Orissa*. 6 parts. Botanical survey of India. Calcutta (Repr. Edn. 1961).
- Hooker JD (1885) *Flora of British India*. Reprinted Edition 1954. Vol. IV. L. Reeve and Co. Ltd., England
- Ito Y & Barfod A (2014) An updated checklist of aquatic plants of Myanmar and Thailand. *Biodiversity Data Journal* 2: e1019. [DOI: 10.3897/BDJ.2.e1019]
- Jyothi PV & Sureshkumar S (2018) Patterns of Vegetation Dynamics across Mild Disturbance Gradient in a Freshwater Wetland System in Southern India. *Wetlands* 38(4): 807–817.
- Kar SK, Tripathy PK, Mohanty SK, Acharya PK & Panda PC (2016) Additions to the flora of Chilika lake and its immediate neighbourhood. *Journal of Economic and Taxonomic Botany* 40(3–4): 134–150.
- Kumar R, Kumar R, Om Prakash, Srivastava RM & Pant AK (2019) Chemical composition, in vitro antioxidant, anti-inflammatory and antifeedant properties in the essential oil of Asian marsh weed *Limnophila indica* L. (Druce). *Journal of Pharmacognosy and Phytochemistry* 8(1): 1689–1694.
- Lansdown RV (2014) *Limnophila indica*. The IUCN Red List of Threatened Species. e.T169024A45461779. <http://dx.doi.org/10.2305/IUCN.UK.2014.1.RLTS.T169024A45461779.en>. (accessed: 30 Mar. 2019).
- Les DH (2018) *Aquatic Dicotyledons of North America: Ecology, Life History, and Systematics*. CRC Press, Taylor & Francis group, Boca Raton, London, New York
- Mohan Ram HY & Rao S (1982) In-vitro induction of aerial leaves and of precocious flowering in submerged shoots of *Limnophila indica* by abscisic. *Planta* 155: 521–523.
- Naskar KR (1990) *Aquatic & Semi-aquatic plants of the lower Ganga delta*. Daya Publishing House, Delhi.

- Panda M, Samal RN, Bhatta KS, Lenka S, Rout J & Patra HK, Nanda S (2018) Diversity and distribution of vascular macrophytes in Ansupa Lake, Odisha, India. *Bonorowo Wetlands* 8(1): 1–12.
- Philcox D (1970) A taxonomic revision of the genus *Limnophila* R. Br. (Scrophulariaceae). *Kew Bulletin* 24(1): 101–170.
- Prajeesh P, Ratheesh Narayanan MK & Anil Kumar N (2014) Diversity of Vascular Plants Associated with Wetland Paddy Fields (Vayals) of Wayanad District in Western Ghats, India. *Annals of Plant Sciences* 3 (05): 704–714.
- Rahangdale SS & Rahangdale SR (2017) Floristic diversity of Bhimashankar Wildlife Sanctuary, northern Western Ghats, Maharashtra, India. *Journal of Threatened Taxa* 9(8): 10493–10527.
- Rahman MO (2006) Scrophulariaceous taxa in Bangladesh. *Bangladesh Journal Plant Taxon* 13(2): 139–154.
- Rao S & Mohan Ram HY (1981) Regeneration of whole plants from cultured root tips of *Limnophila indica*. *Canadian Journal of Botany* 59: 969–973.
- Rutishauser R (1999) Polymerous leaf whorls in vascular plants: Developmental morphology and fuzziness of organ identities. *International Journal of Plant Sciences* 160: S81–S103.
- Saxena HO & Brahamam M (1994-96) *The flora of Orissa*. Vol. I–IV, RRL & OFDC Ltd., BBSR.
- Shi LWS (1998) *Limnophila* R. Brown, Prodr. 442. 1810. *Flora China* 18: 26–28.
- Sujana KA, Saravanan R & Pandey AD (2015) Distribution of Aquatic Macrophytes in Balasore District, Odisha. In: Rawat *et al.* (eds) *Aquatic Ecosystem: Biodiversity, Ecology and Conservation*. Springer India, pp. 1–12.
- Suthari S, Vatsavaya SR & Majeti NVR (2018) Ethnobotanical Explorations in Telangana, the Youngest State in Union of India: A Synoptic Account. In: Ozturk M & Hakeem KR (eds) *Plant and Human Health: Ethnobotany and Physiology*. Vol. 1, Springer, Switzerland. pp. 68–123.
- Tucker AO & DeBaggio T (2009) *The Encyclopedia of Herbs: A Comprehensive Reference to Herbs of Flavor and Fragrance*. Timber Press, Inc.