

## TAXONOMY, AUTECOLOGY AND DISTRIBUTION OF *NAJAS MARINA* L. (NAJADACEAE) IN BANGLADESH

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### Abstract

Detailed taxonomic description of *Najas marina* L. including information on flowering and fruiting time, autecology, and distribution in Bangladesh are provided. The diagnostic characters with illustrations and behavioural patterns of different habitats are also provided. Presence of *Najas marina* in Joydia baor indicates that the water quality of this baor is fairly good and minor human interference of the habitats.

### Introduction

*Najas marina* L. (Holly-leaved Naiad) is an annual, dioecious, mostly robust, spiny naiad, rooted, vascular slender herb which grows as completely submerged in shallow habitats (up to 3 m deep), with rooting extensively into the bottom sediments. *Najas* is the largest hydrophilous genus and contains approximately 40 species (Handley and Davy, 2000). In different countries of the world, it has become rare. *Najas marina* is listed as Vulnerable in the British Red Data Book and in the IUCN European Red Data Categories and is therefore specially protected under the Wildlife and Countryside Act 1981 (Wigginton, 1999). This species is also enlisted in Red Data Book in Germany (Huang *et al.*, 2001; Rüegg *et al.*, 2017). Due to the rarity and lacking of *N. marina* in Britain and Europe, detailed information on autecology and life history is absent in this area. There have been no reports of male individuals and the absence of male flower of *N. marina* in Britain, suggested the opinion its prolific seed production is entirely apomictic (Stace, 1997; Preston and Croft, 1997). However, in 2000 discovery of male plants of *Najas marina* L. was reported in Britain by Handley RJ and Davy AJ and illustrated the features of male flowers. The uncommonness of *N. marina* in Europe is due to the limited availability of appropriate habitats and problems of dispersal mechanism. Temperature plays also an important role. *N. marina* appears to be favoured by a continental climate with relatively warm summers and cold winters (Handley and Davy, 2005).

Triest (1988) distinguished 12 subspecies and four varieties under *Najas marina* based primarily on sizes of seed, ovary, style, stigma, and anthers. Khan and Halim (1987) have mentioned five species of *Najas* from Bangladesh that do not include *N. marina*. Hooker (1888) reported *Najas marina* L. under the name *Naias major* All. mentioning its distribution throughout India in fresh and brackish water ascending to 8000 ft in Western Tibet. He also placed a note that "The Indian species of this genus require a very close examination, which I regret to say I have no materials of flowers and fruits sufficient to enable to undertake." Prain (1903) reported *Najas marina* from the then East Bengal which actually included the greater Mymensingh, Dhaka, Cumilla, Noakhali and Barisal area. Prof. M Salar Khan and A.M. Huq collected a sterile specimen of this species from Fatehpur Baor, Moheshpur, Jessore district in 1991 which was

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preserved in Bangladesh National Herbarium (BNH, col. no. 8445). No taxonomic and ecological publication regarding *N. marina* specimen has been found in Bangladesh so far. The present species of *N. marina* was collected recently from baor areas of Jhenaidah district in 2020 from Bangladesh. So far a total of 9 species namely, *Najas dichotoma*, *N. foveolata*, *N. graminea*, *N. indica*, *N. kurziana*, *N. lacerata*, *N. major*, *N. marina*, *N. minor* have been reported from Bangladesh. In Bangladesh, no previous study on taxonomy, autecology and distribution of *N. marina* has been found. Therefore, the present study has been conducted on the taxonomy, autecology and distribution of *Najas marina* in Bangladesh.

### Materials and Methods

The plant materials of this Holly-leaved Naiad were collected from the Joydia baor, Safdalpur union of Kotchandpur upazila of Jhenaidah district of Bangladesh through a hydrobiological expedition carried out from June 2020 to July 2022. This oxbow structure of this baor is usually generated due to the change of the direction of the river. Joydia baor is a permanent water body which is the largest baor of Bangladesh. It is located between the latitude 23°26'40.6" N and longitude 88°55'47.4" E. Total area of the baor is around 2.16 square kilometers. The minimum depth is 3.27 m at its southern part and the maximum depth is 9.7 m at the eastern part of its middle portion. The macrophyte sample was collected from 0.5 m depth of the littoral area of the baor. The collected plant samples were then put in a large air tight ice bag with some water inside. It was then transported to the Phycology, Limnology and Hydrobiology Laboratory, Department of Botany, University of Dhaka. Plant material was always examined in fresh condition immediately after sampling for morphological characteristics as described here. Some materials were preserved as herbarium sheet in this laboratory. The some living plant samples were planted in a concrete house (1 × 0.5 m length, depth 0.40 cm) in the Botanical Garden, Department of Botany, University of Dhaka, for *ex-situ* conservation and further study. Both *in-situ* and *ex-situ* culture were made for detailed taxonomic and autecological study. A total of 24 physico-chemical parameters of water samples were measured for two years study. The water samples were collected between 7.30 am to 9.30 am. After collection, all water samples were preserved in an insulated Ice box using cool packs and were transported to Phycology, Limnology and Hydrobiology Laboratory, University of Dhaka for analysis. The preserving temperature was ≥ 10°C. All samples were transported to the laboratory and processed within 24 hours of collection. Different autecological parameters were studied with the help of Alfasane *et al.* (2013); Golterman *et al.* (1978) and Huq and Alam (2005). Photographs of internal section of leaf and stem were taken with the help of a compound microscope, Nikon (Optiphot, UFX-11A) fitted with a camera (Nikon FX-35 WA, Japan).

### Results and Discussion

Through two years' long critical studies, detailed data on taxonomic characteristics and autecology of *Najas marina* have been collected with its distribution. The relevant photographs and illustrations are presented in Figs 1-3.

### ***Najas marina* L. Sp. Pl. : 1015 (1753)**

*Synonyms:* *Najas gracilis* (Morong) Small, *N. major* All., *N. marina* var. *recurvata* Dudley, *N. major* var. *angustifolia* A. Braun ex K. Schum, *N. marina* var. *genuina* K. Schum.

*Common names:* Spiny water Nymph, spiny-leaf naiad alkaline water-nymph, Holly-leaved Naiad, Saw tooth, Sea Naiad, Marine Naiad.

*Bangla name:* Kanta Shewla

*Community structure:* *N. marina* is one of the rare species in Joydia baor growing with *Ottelia alismoides* L., *Ceratophyllum* L., *Myriophyllum* L., *Utricularia* L. and *Vallisneria spiralis* L. (Fig. 1a). It is mostly robust, spiny, extensive root, slender herb, completely submerged, grown up to 3 m depth. It is only distributed certain restricted area of this baor.

### Taxonomic description

#### *Morphology*

(Figs 1-3)

*Root:* These submerged plants found to be loosely anchored to submerged soil with extensive long roots. Roots arise from each internode which lie near the soil surface. Root length usually up to 22 cm. Young roots are light pink in colour and mature ones are white (Fig. 1d).

*Stem:* Stems are round, much branched, green to brownish, with scattered large spine-tipped prickles. Stems up to 150 cm long and the diameter of stem up to 2.5 mm, stem mostly armed with spines on the internodes (Fig. 1i, 2a). The main stem is round, deep brown or black in color. Stem of the plant is spiny of 2 mm length, most usually 1.5 mm in length. The stem spines are brown, prominent, hard and prickly. Many lateral branches arise from the main stem of different length (Fig. 1b,c,i,e). All branches have rosette like arrangement of 8 to 9 leaves at the top. Every branch has nodes and internodes, the length of each internode 40-60 mm and every connection of nodes that remain in horizontally roots and at each node there is found a group of 6 leaves whorled and a single leaf, these are placed in opposite direction.

*Leaf:* Leaves in a whorl of 3 or 4 leaves per node, submerged, acute, with spiny teeth on both margins and ventral side on midrib, opposite, green or light green, some are brown in color at maturity. Leaf sheaths are round or funnel shaped with minute spine at the two side of the sheath apex and the length of the sheath up to 5 mm. Leaf size varies in length, usually 35-47 mm without sheath, 60 to 66 mm long with sheath, leaves breadth with spine 3.0-6.5 mm and without spine the leaves breadth 2.5-4.5 mm. Leaves are spiny at both sides and prominent 3 dentate tip at the apex of the leaf tip remains and looks like a minute crown shape structure. Leaves with spines on the midrib in the ventral side 2-3 mm in length and 1.5 mm in breadth and 1-7 in numbers are present. Leaves broader than 1.5 mm including teeth on both sides, less than 20 leaf teeth on each margin and leaf teeth on excrescences consist of several brown cells; leaf teeth shorter than 2 mm (Fig. 1f-h). Leaves without septa and fibres. Areoles irregularly arranged.

*Flower:* *Najas marina* is a dioecious plant. Flowers are minute, ellipsoidal or oval, arise singly, or sometimes several together, on a fertile shoot with suppressed internodes within a sheath axil. At young stage bud of flowers are whorled by leaf sheath (Fig. 2). Male and female flowers are separate on separate plants and also bear different flowers with slight morphological differences.

*Male flower:* Male flower arises from internodes and has spathe (covered with axial sheath), green/light green in colour but some field observations of male flowers appeared conspicuously pale in colour, apparently because the white pollen grains were visible through the anther wall and thin, membranous perianth (Fig. 2c-g). Subsequently, darker male flowers were found. The pale flowers were close to dehiscence, with mature pollen. In these flowers the pollen-filled anther was particularly visible, because elongation of the filament prior to dehiscence caused the anther to split the spathe from the apex downwards. The pollen grains are released rapidly from an apical split of the anther. Thereafter, pollen is released slowly. A large amount of pollen is dispersed into the water within this short period. When the initial stage of anther dehiscence in *N. marina*, it has been noticed that the dense clouds of pollen grains being released into the water. The pollen grains are somewhat heavier than water (Fig. 2g).

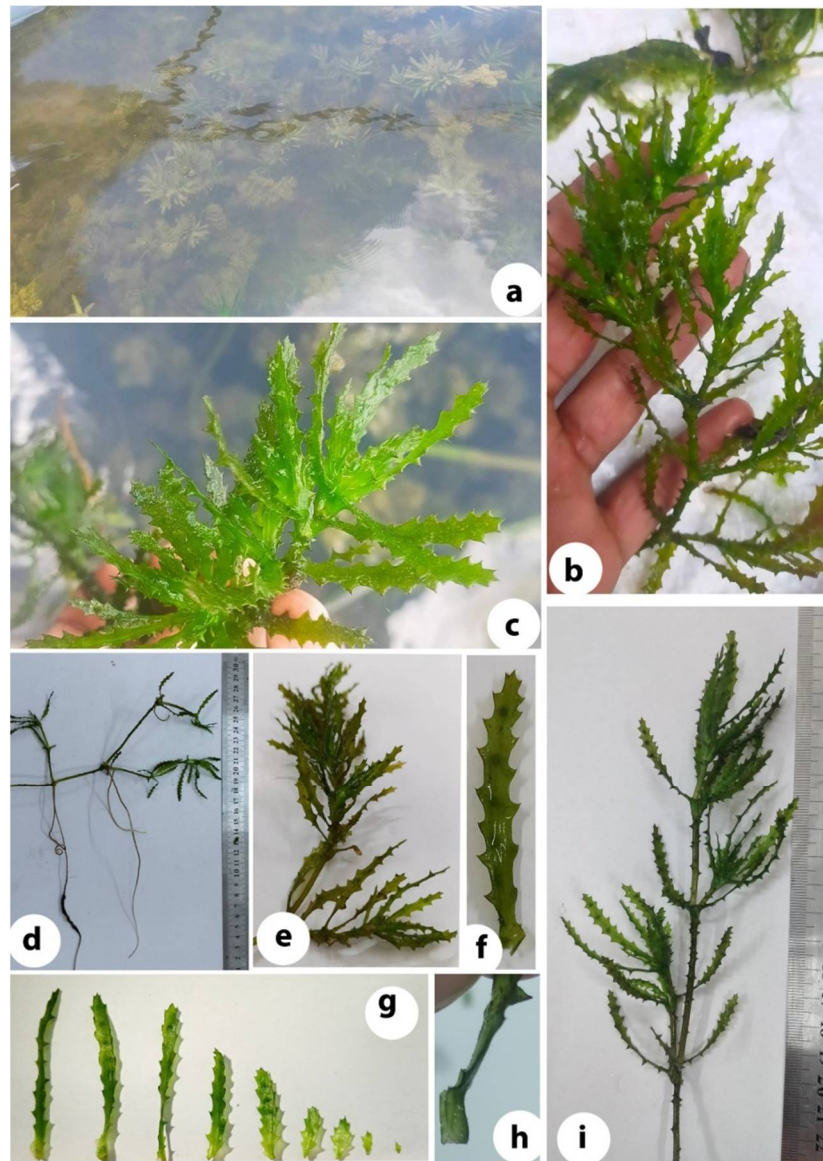


Fig. 1 (a-i). a. Habitat, b-c. Leaf arrangement just after collection, d. Showing root and spiny stem, e. Node with a whorl leaf and top rosette arrangement, f-g. Leaf with dentate tip and margins, h. Leaf sheath with spines, i. Stem and arrangement of lateral branches with spines.

The male flower also possesses small crown like spine at the top. Each male flower has single anther with 4 locules in transverse section which is called tetrasporangiate anther (Fig. 2f). These 4 locules of the male flower can also be ensured with prominent projection. Length of male flower 4.0-6.5 mm and width 2 mm, the crowned tip is 0.5 mm in length. Flowers were also found in which the anthers had clearly dehisced, leaving the anther filament and the white viscous matters of the four locules, that dissolved in water. Male flowers are similar in size and shape to the maturing fruits of the female plant, and therefore they can be difficult to distinguish in the field.

The phase during which the male flowers have a pale colour provides a reliable field diagnostic feature but this was evident only during August of the year (Fig. 2c-g).



Fig. 2 (a-j). a. Stem with arrangement of spines, b. Leaves showing dorsal spines, c. Male flower of *Najas marina* with spathe protruding above the anther to form characteristic spines, d) single flower with characteristic crown, e) Longitudinal section of the flower, f) transverse section of the flower showing 4 locules, g) Dense clouds of pollen grains being released, h-i) Female flowers of *Najas marina* in a fertile shoot, j) Fruits producing in the fertile shoot.

*Female flower:* Female flowers also arise from leaf axils. They are smaller in size than the male flowers, more or less oval shaped. Having a single ovule with 2 stigma/style at the top,



stigma/style is brown in colour. The length of female flower is 4.5-5.0 mm and width 1.0-1.5 mm with top stigma/style of 1 mm long (Fig. 2h-i).

**Fruit:** Fruit (achene) with an oval seed, 2.2 to 4.5 mm long, irregularly pitted on the surface, reddish-brown at maturity (Fig. 2j).

### **Anatomy**

**Leaves:** There are lower and upper epidermis with hexagonal mesophyll tissue of the transverse section of the leaves (Fig. 3a-b). In the margin of the leaves have various brown colour cell where the leaf teeth found.

**Stem:** There are various air space present of the cortex in the stem in transverse section. One cell thick epidermis and broad cortex is connected with the middle portion of the stem where vascular bundle present. Two vascular bundles are present vis-a-vis position (Fig. 3c-d).

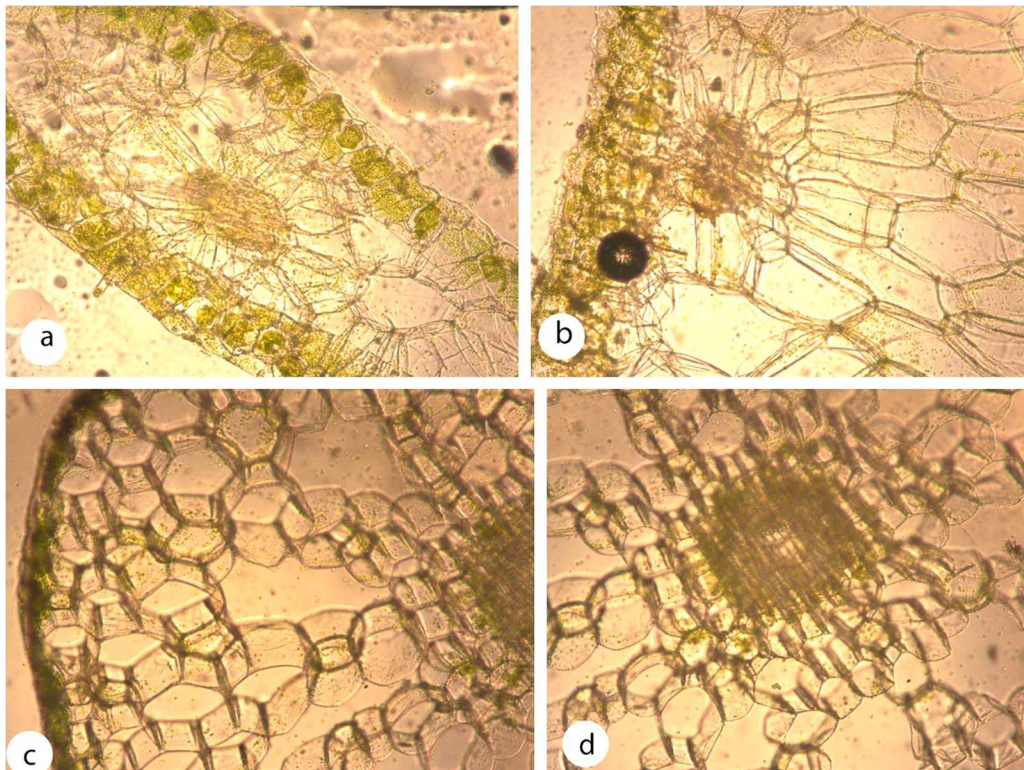


Fig. 3. a) T. S. of leaf of *Najas marina* b) T.S. of leaf specified in midrib c,d) T.S. of stem of the plant *Najas marina*.

The easiest way to identify the species, *Najas marina* L. is the visible toothed leaves with scattered prickles along the midrib and on the stems. It is also the only dioecious *Najas*, where the others are monoecious. In June and July, only plants bearing female flowers were observed; despite meticulous examination of a considerable quantity of plant material, male flowers could not be found. Plants apparently had only female flowers or no floral structures at all. However, in August both male and female flowers were identified for the first-time on separate plants. The

dense beds, with near-continuous cover, and the branching growth form of *Najas marina* at Joydia baor Jhenaidah combine to create considerable difficulty in distinguishing individual plants. The bases of the stems often become covered in sediment and root at the covered nodes making the identification or collection of individual plants impossible. Nevertheless, it was clear that the ratio male flower bearing stems in these beds was high then of female plants perhaps as high as 10: 1, and that male stem cocooned in distinct patches, suggesting that isolated, individual males were surrounded by females. With some care it was possible to collect entire plants of *N. marina*.

**Autecology:** Macrophytes have been used as bioindicators for eutrophication assessment in freshwaters required by the European Water Framework Directive (WFD, Rüegg *et al.*, 2017). *Najas marina* L. is one of the species used for implementation of the reference condition (equal to high ecological status) is defined as ‘‘natural, undisturbed/minor human impacted’’ and differs according to lake type (Wallin *et al.*, 2002) in the European Water Framework Directive (WFD; Schaumburg *et al.*, 2004; Stelzer *et al.*, 2005). Presence of *Najas marina* of this baor indicates the water quality of this baor is fairly good and minor human disturbance of the habitats. *Najas marina* was first found in North America in 1864 in central New York's Onondaga Lake near Salina, New York (Stuckey, 1985). This plants can grow up to 3 meter depth in brackish or highly alkaline ponds, lakes, and coastal, inland marshes as well as fresh water habitats. It can reproduce by seed and fragmentation (Tarver *et al.*, 1986). Studies by Vierssen (1982) have shown seed germination of *N. marina* to be best in decomposing organic matter, at 24°C under dark conditions. Flowering and fruiting time from June to October. Plants prefer to grow in sandy, loamy and clay as well as acid, neutral and alkaline soils. It can grow in semi-shade (light woodland) or no shade. Joydia baor considered to be a potential source of fish population and this fish population largely depends on phytoplankton (primary producer) of the baor as well as water quality. A total of 24 physico-chemical parameters were studied to assess the water quality of Joydia baor. The range of mean values of physico-chemical parameters of this baor were : air temperature 29.27-30.6 °C; water temperature 28.44-29.95 °C; turbidity 1.93-3.16 NTU; Electric Conductivity 87.35-172.15 µS/cm; TDS 98.21-195.05 mg/l; pH 6.32 to 7.20; Alkalinity 2.59-3.52 meq/l; DO 8.69-9.59 mg/l; TSS 18.86-27.14 mg/l; BOD 0.78-1.70 mg/l; NO<sub>3</sub>-N 0.36-0.42; SRS 6.38-7.44 mg/l; SRP 34.14-45.41 µg/l; SO<sub>4</sub><sup>2-</sup> 21.01-35.11 mg/l; Cl<sup>-</sup> 0.89-1.40) mg/l; F<sup>-</sup> 0.25-0.35 mg/l; NO<sub>2</sub><sup>-</sup> 0.05-0.09 mg/l; Na<sup>+</sup> 0.25-0.41 mg/l; K<sup>+</sup> 0.39-1.55; NH<sub>4</sub><sup>+</sup> 0.45-0.89 mg/l; Ca<sup>2+</sup> 1.22-4.38 mg/l; Mg<sup>2+</sup> 0.39-0.89 mg/l; Mn<sup>2+</sup> 0.39-0.89 mg/l and Fe<sup>2+</sup> 0.25-1.13 mg/l. The ranges of this autecological parameters indicating the water quality is suitable for *N. marina* growth in this habitat. Many free-floating, emergent, and submerged macrophyte species have the potential to improve water quality by binding and removing nutrients, organic contaminants, and even heavy metals (Dhote and Dixit, 2009). Moreover, the narrow ecological niche of certain macrophyte species makes them suitable indicator organisms for classification of the ecological quality of lakes and rivers (Melzer, 1976; Penning *et al.*, 2008; Schneider *et al.*, 2000; Søndergaard *et al.*, 2010).

**Distribution:** This plant is widely distributed across Europe, Asia, Africa, Australia, the Americas and many oceanic islands. *Najas marina* has cosmopolitan in distribution, (Sculthorpe, 1967; Les *et al.*, 2003). In tropical Asia, *N. marina* is widely distributed in China (Wang *et al.*, 2010), India (Cook, 1996), Indonesia (de Wilde, 1962), Pakistan (Cook, 1996), Sri Lanka (Cook, 1996), Taiwan (Yang, 2000) and Thailand (Ito, 2016). Spiny Naiad has a world-wide distribution but a scattered one in North America, considered a rare species in Minnesota and introduced in Wisconsin, even potentially invasive in some states. In Bangladesh, It has been reported from East Bengal previously but at present only found in Jhenaidah district.

## Conclusion

Apart from scientific researches, this baor is a very important natural resource of Bangladesh. Day by day people is knowing about the scenic beauty of this area and getting more attracted to it. As a result its natural beauty as well as biodiversity is getting severely hampered. As there is no record of its occurrence in any other places in Bangladesh, *Najas marina* should be enlisted as endangered species in Red Data Book of Bangladesh. From the results of this research work it has become apparent that the Joydia baor is a very opulent lake having enormous significance from ecological points of view. But due to lack of appropriate conservation strategies the baor is being subjected to eutrophication. If proper planning and actions are not taken in near future the baor may get polluted or go through the process of succession. Therefore, implementing adequate and effective initiatives for the improvement of natural features of the baor is very crucial in order to conserve and develop its plant diversity including *Najas marina* sustainably.

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