Naveen Shodh Sansar (An International Refereed / Peer Review Multidisciplinary Research Journal)
RNI No.- MPHIN/2013/60638, ISSN 2320-8767, E- ISSN 2394-3793, Scientific Journal Impact Factor (SJIF)- 8.054,
April to June 2026, E-Journal, Vol. I, Issue LIV (54), ISO 9001:2015 - E2024049304 (QMS)

Phytochemical Profiling and Antioxidant Potential of Selected Aquatic Medicinal Plants

Dr. Ragini Sikarwar*

***Assistant Professor and HOD (Botany) Govt. Home Science PG Lead College, Narmadapuram (M.P.) INDIA**

Abstract: Aquatic and wetland associated plants have been helping traditional medicine systems across South and Southeast Asia, sub–Saharan Africa, and Latin America, for generations, but their phytochemical as well as antioxidant capabilities are still way less systematically mapped than those of terrestrial medicinal plants. Here we gather reported lab results from six species that have clear medicinal credibility and a real aquatic or semi aquatic home: sacred lotus (Nelumbonucifera), water hyacinth (Eichhorniacrassipes), water spinach (Ipomoea aquatica), blue red water lily (Nymphaea nouchali), Indian pennywort (Centellaasiatica) and the cyanobacterium Spirulina platensis. For each one, the reported total phenolic content (TPC), total flavonoid content (TFC), and DPPH/ABTS radical scavenging IC50 figures are taken from the original articles and set side by side, along with the qualitative phytochemical categories that were identified within each species. Looking across all six, phenolic plus flavonoid levels track quite broadly with how strong the free radical scavenging looks, which fits the standard hydrogen atom transfer, and also single electron transfer explanations used for polyphenolic antioxidants. The reviewed work further hints at uses that go beyond human phytomedicine, like using water spinach, and even algal biomass, in aquafeed mixes to help reduce oxidative stress in fish that are raised on farms. Still, there are fairly big inconsistencies between studies: extraction solvent choices, which plant part was sampled, and how the assay was run. Those issues make direct comparisons between species difficult, and they are addressed here, plus future routes for more standardized research are outlined.
Keywords: phytochemical screening, DPPH assa, Spirulina platensis, aquatic medicinal plants, antioxidant activity, Nelumbonucifera.

Introduction - Reactive oxygen species (ROS) show up sort of continuously, as a by-product of normal aerobic metabolism, and when the environment gets rough, or inflammation steps in, or during ageing, their formation can end up going faster than what the body s own enzymatic and non-enzymatic defenses can manage. That mismatch, and it is usually called oxidative stress, has been tied to the worsening of cardiovascular disease, diabetes, neurodegenerative problems and also several cancers. Because of that link, finding antioxidants that are effective yet safe has stayed pretty much a long-running topic, in pharmacological research for decades.

Synthetic antioxidants like butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are still used a lot in food and pharma, however worries about their long-term safety, have nudged both industry and academic groups toward plant-derived replacements. Most of the focus has gone to terrestrial medicinal plants, and there are already broad phytochemical collections for examples such as turmeric neem and ginger. Aquatic and wetland-associated plants, though, have gotten less attention overall, even though they have a long history of use in Ayurveda, traditional Chinese medicine and a bunch of local folk-medicine practices across Asia and Africa.

Also there's a sort of biological angle to why we might expect aquatic macrophytes to be a productive source of antioxidant phytochemicals. Plants that grow in, or right along the edges of water bodies, are usually dealing with shifting light strength, herbivory from aquatic fauna, microbial and fungal pressure, and in many situations nutrient or pollutant loading that comes in from the surrounding water. The production of secondary metabolites, like phenolics, flavonoids, tannins, and alkaloids, is considered one of the main defence tactics plants use under these kinds of stress. And several of the species reviewed here are known to build up these compounds at levels on par with, or even above, well known terrestrial medicinal herbs, depending on the study.

This review puts together and compares the published phytochemical and antioxidant information for six species that really have aquatic, semi-aquatic, or wetland margin habitats, plus a documented traditional or newer medicinal use: Nelumbonucifera, Eichhorniacrassipes, Ipomoea aquatica, Nymphaea nouchali, Centellaasiatica and

Spirulina platensis. The aim isn't to add brand new experimental results, but rather to integrate the already peer reviewed evidence into one comparative narrative, emphasizing what keeps turning up consistently, where different papers don't agree, and how useful this literature is for aquaculture, nutraceutical development, and pharmacology.

Aquatic Medicinal Plants: An Overview: Aquatic and semi aquatic medicinal plants can be kind of broadly sorted by they growth habit into submerged macrophytes, which are largely or fully beneath the water surface, then floating macrophytes, those free floating ones out on the surface where they can be rooted or not, and also emergent or marginal species that are rooted in submerged or waterlogged soil, but still most of the plant body sits above the water. In a way the six species reviewed here cover this whole span: Nymphaea nouchali is a rooted floating leaved type, Eichhorniacrassipes is the sort of free-floating aquatic weed that shows up fast, Nelumbonucifera comes in as rooted, with both floating leaves and emergent leaves. For the more creeping, marsh margin and semi aquatic herbs, Ipomoea aquatica and Centellaasiatica are often seen along ditches, paddies, and pond edges. Then Spirulina platensis, more formally placed as Arthrospira platensis, is a filamentous photosynthetic cyanobacterium native to alkaline lakes, and it is now cultivated commercially, in open ponds, and also in photobioreactors all over the world.

All six are described as having traditional or more modern medicinal use. Nelumbonucifera takes up a big role in Ayurvedic practice and also in traditional Chinese medicine, where its seeds, rhizome, leaf and flower are applied in several ways for cardiotonic effects, fever reducing action and also astringent purposes. Nymphaea nouchali , which is the national flower of Bangladesh and Sri Lanka, shows up in South Asian folk medicine for diabetes, liver related troubles and inflammation. Centellaasiatica, often called gotu kola or Indian pennywort, is among the most frequently studied herbs for wound repair and brain support, coming from South and Southeast Asian traditional systems. Ipomoea aquatica, known as water spinach or kangkong, is eaten as a leafy vegetable and it also functions as a folk remedy for digestive issues and hepatic complaints across South and Southeast Asia. Eichhorniacrassipes, despite being famously invasive as one of the world's worst aquatic weeds, is more recently drawing attention for research focused on antioxidant and antimicrobial phytochemical sources, partly as a way of giving value to an otherwise troublesome biomass. Spirulina platensis meanwhile, is already a well-established nutraceutical and functional food component, sold worldwide for its protein, pigment, and antioxidant profile.

Literature Review Approach

This review is based on peer-reviewed studies pulled from PubMed, ScienceDirect, Wiley Online Library, MDPI, Springer, and other related academic databases. We used combinations of each species scientific name with terms like, phytochemical antioxidant total phenolic content total flavonoid content and DPPH. Preference was given to work that reports numerical total phenolic content, (TPC) total flavonoid content, (TFC) and or half-maximal inhibitory concentration, (IC50) from DPPH, ABTS, or similar radical-scavenging tests. Whenever it was available, this was reinforced by more qualitative phytochemical screening data.

Since the surveyed studies differ in plant part, extraction solvent, extract concentration units, and also the reference standard, the information gathered in Tables 1 and 2 and Figures 1 and 2 is not the outcome of a controlled, side-by-side comparison. Instead it should be read as a kind of illustrative synthesis of what has been independently reported for each species, rather than as measurements that are directly equivalent. This constraint, common to most narrative reviews in phytochemical work, is taken up again in Section 8.

Phytochemical Profiles and Antioxidant Potential of Selected Species

Nelumbonucifera (Sacred Lotus): Nelumbonucifera (family Nelumbonaceae) is one of the most thoroughly examined aquatic medicinal plants and it has been described as carrying a wide range of bioactive constituents, like alkaloids, flavonoids, tannins, saponins, plus phenolic acids. These compounds appear to be distributed in unequal ways across the seed, leaf, flower, rhizome, and stamen. So, a hydro-alcoholic seed extract of lotus was reported to contain 7.61% w/w total phenolic content, and it also showed very strong DPPH scavenging behavior, with an IC50 value of 6.12 µg/mL, which was lower, thus more potent, than the rutin reference standard used in the same work. In addition, the very same extract demonstrated hepatoprotective and renoprotective actions against carbon tetrachloride induced oxidative injury in rats.

In contrast, leaf extracts often look richer in phenolic and flavonoid amounts but they tend to show less powerful radical-quenching performance than the seed extract mentioned above. For example, methanolic and aqueous leaf extracts were described with total phenolic contents of 147.63 and 85.01 mg gallic acid equivalents (GAE) per gram of dry mass, respectively, and flavonoid levels of 41.86 and 35.38 mg quercetin equivalents (QE) per gram. Yet their DPPH results moved in the opposite direction, with higher, meaning weaker, IC50 values of 514.36 and 1699.47 µg/mL. Meanwhile, GC-MS based screening of lotus rhizome from an Indonesian freshwater source revealed 238 distinct compounds in the crude ethanolic extract, including linoleic acid, stigmasterol, and betulin. That rhizome fraction showed a more moderate DPPH IC50 of 57.88 ppm.

Flower extracts have also been evaluated in similar lines. A methanolic lotus flower extract, for instance, produced an antioxidant EC50 of 0.17 mg/mL against DPPH

radicals. Overall, the seed extract seems to stand out among lotus tissues because of its unusually strong ability to neutralize radicals, while leaf, rhizome, and flower extracts appear more moderate in that respect, even if they still remain meaningfully active.

Eichhorniacrassipes (Water Hyacinth): Eichhorniacrassipes (family Pontederiaceae) , is that fast-growing free-floating aquatic weed from South America, and it is now naturalised across tropical and subtropical waterways around the globe where it is usually seen as an ecological and economic nuisance, not really a usable resource. What's interesting, though, is that over roughly the past decade phytochemical work has repeatedly shown phenolics, tannins, flavonoids and saponins in extracts from leaves, flowers, and petioles , while alkaloids are mostly reported as absent , or "negative" in the usual screening.

For example, a hydro-methanolic leaf extract was described with a total phenolic content of 491.2 mg GAE/g, and a total flavonoid content of 76.8 mg quercetin equivalents per gram. That's notably higher than the matching aqueous extract (258.3 mg GAE/g and 46.1 mg QE/g). The hydro-methanolic extract also looked stronger in antioxidant assays, giving 221.52 mg ascorbic acid equivalents per gram, versus 97.07 for the aqueous one, and it showed antibacterial action against Escherichia coli and Pseudomonas aeruginosa.

In another study, extracts from water hyacinth flowers were tested using three solvents that increase in polarity. Here the methanolic extract was way more active overall, with a DPPH IC50 of 35.83 ppm, while the ethyl acetate extract came in at 950.71 ppm and the n-hexane extract at 1085.31 ppm. This highlights a strong solvent–polarity effect, which fits the idea that polar phenolic antioxidants tend to perform better. Petiole extracts were also evaluated for cytotoxicity against MG-63 osteosarcoma cells, alongside antioxidant testing. They showed 57.95% DPPH and 60.47% ABTS scavenging at 400 µg/mL, and an IC50 of 177.65 µg/mL against the cancer cell line. So overall, the plant's bioactive potential seems to go past plain radical scavenging, even if it sometimes gets framed as only that. Ipomoea aquatica (Water Spinach)

Ipomoea aquatica (family Convolvulaceae), you know, usually called water spinach or kangkong, is kind of a semi aquatic vegetable, and also a traditional remedy that people consume a lot across South and Southeast Asia. In one broad metabolite profiling work using UPLC-qTOF-MS/MS they reported more than 65 compounds, and 36 secondary metabolites in the plant overall, with most of them being polyphenolic type substances, plus some alkaloids and terpenoids in the mix. That same study gave total phenolic and flavonoid values of 142.43 mg GAE/g, and 43.06 mg rutin equivalents (RE)/g too, and they also measured ABTS and DPPH IC50 at 0.087 mg/mL and 0.122 mg/mL. On top of that, the extract showed a detectable ability to reduce UV, and hydrogen-peroxide caused DNA damage, in vitro. Now, since this journal is looking at aquatic systems and aquaculture, there was another HPLC-DAD-based investigation that basically zoomed in on water spinach as a candidate bioactive ingredient for fish feed, because it is already used as part of aquafeed recipes. They described a crude ethanolic extract IC50 of 149.30 µg/mL against DPPH radicals. Interestingly, the aqueous fraction came out better, with 176.59 µg/mL, while the n-hexane fraction was weaker at 365.07 µg/mL, and they ended by saying that the plant polyphenol, and flavonoid levels may help justify its inclusion in feed blends intended to boost disease resistance plus stress tolerance in farmed fish. They also hinted that anti nutritional factors would still need to be handled when designing the feed. And in comparison, to land spinach, the terrestrial cousin, both papers? similar results showed water spinach had the stronger antioxidant capacity, and that lined up with water spinach showing the higher total phenol and flavonoid content.

Nymphaea nouchali (Blue-Red Water Lily): Nymphaea nouchali (family Nymphaeaceae) is said to be the national flower of Bangladesh and Sri Lanka, and yes it's a rooted floating-leaved aquatic herb, used in South Asian folk and Ayurvedic practice kinda broadly. People use it for diabetes, inflammation, liver disorders, and also as a sort of general tonic. One report described a hydro-alcoholic seed extract that showed very high tannins, about 195.84 gallic acid equivalents per gram, plus total phenolics at 179.56 GE/g , and flavonoids at 23.55 quercetin equivalents/g. In the DPPH and nitric oxide tests, and also for lipid peroxidation, it gave IC50 values around 42.82, 23.58, and 54.65 µg/mL respectively. It also had a high overall antioxidant capacity, reported as 577.73 mg vitamin E equivalent per gram of extract, which sounds pretty impressive.

Then there's a fuller metabolomic angle, a UHPLC-QTOF-MS study on Egyptian populations of Nymphaea nouchali, where researchers annotated 185 secondary metabolites across flower, leaf and stem. Those compounds ranged through phenolic acids, ellagitannins, flavonoids, anthocyanins, and even alkaloids. The flowers, somehow, showed the strongest antioxidant activity among the three organs. The IC50 values were given as 45.15 µg/mL for DPPH, and 5.02 µg/mL for ABTS scavenging, and the same work also pointed to acetylcholinesterase inhibition, which is often discussed for possible cognitive use. Related work on water lily stems from Bangladesh found more moderate DPPH IC50 values, roughly 28.48 to 36.67 µg/mL, for red and white cultivars respectively. Besides that, there was also appreciable mineral and protein content, so the plant stays used as both something like a food plus a medicinal resource, you know.

Centellaasiatica (Indian Pennywort / Gotu Kola): Centellaasiatica (family Apiaceae) tends to show up, you know, in marshy waterlogged and pond-margin places across tropical Asia. It's also basically one of the most pharmacologically researched semi-aquatic medicinal

herbs, mainly because of its triterpenoidsaponins—asiaticosidemadecassoside, asiatic acid and madecassic acid—those are the backbone of its clearly described wound-healing action. Still, beyond those triterpenoids, the plant carries a notable store of phenolics plus flavonoids, and that's tied to a lot of its antioxidant power, in a more or less straight forward way.

In one report, a chloroform-soluble fraction of Centellaasiatica had the top phenolic level (155.46 mg GAE/g) and flavonoid level (345.17 mg QE/g) out of the solvent fractions that were tested. That same fraction also turned out to have the most forceful DPPH scavenging effect in the group, with an IC50 value of 15.31 µg/mL. They also observed a positive relationship between flavonoid abundance and antioxidant performance, with $r^2 = 0.894$, and it looked pretty convincing. In another separate study, an aqueous leaf extract gave a less impressive DPPH IC50 of 31.25 µg/mL which is about twelve-fold weaker than the ascorbic acid benchmark (2.50 µg/mL). But even so, it remained in the same rough range as the BHT standard (7.58 µg/mL) that was used in that particular experiment; moreover, the aqueous extract showed cytotoxic activity on melanoma, breast cancer, and glioma cell lines.More comparative work, focused on shoot, callus, and cell-suspension cultures, suggested that the callus extract was the strongest overall. It reached an IC50 of 10 µg/mL in the DPPH assay, and it only just edged out the ascorbic acid standard (IC50 26.25 µg/mL) within that specific run, so yes, it's a narrow difference but a real one.

Spirulina platensis (Arthrospira platensis): Spirulina platensis, now more formally reclassified as Arthrospira platensis, is filamentous and photosynthetic, a cyanobacterium grown commercially all over the world, sort of as a protein heavy nutraceutical and functional-food ingredient. Its antioxidant effect is usually pinned mostly on the blue pigment phycocyanin, which is a phycobiliprotein, plus beta-carotene and a smaller set of phenolic compounds, and not so much on terpenoid or alkaloid families that tend to dominate the vascular plant discussion we talked about above.

In whole-biomass work, researchers reported a total phenolic content of 40.45 mg/g at the highest biomass concentration tested. Along with that, DPPH radical inhibition increased when the biomass concentration went up. When phycocyanin is isolated and purified, the antioxidant performance tends to come out stronger and more repeatable than what you see with crude biomass extracts. For example, one paper using a green aqueous two-phase extraction setup measured phycocyanin with DPPH and ABTS IC50 values of 38.15 and 25.70 ppm, respectively. Another study, using a Box-Behnken optimisation design, reported IC50 values of 40.70 µg/mL for DPPH, 23.25 µg/mL for ABTS, and 17.74 µg/mL for nitric oxide scavenging.

Also, a comparative analysis looking at tropical Spirulina platensis alongside the seaweeds Gracilariaarcuata and Ulva lactuca found that Spirulina's aqueous extract had the lowest total phenolic content and the weakest radical-scavenging ability among the three. That suggests, within algae as it does within vascular plants, the extraction solvent and the specific target compound family matter a lot for the antioxidant potency you end up measuring.

Comparative Phytochemical and Antioxidant Data:
Table 1 summarises representative total phenolic content, total flavonoid content and DPPH IC50 values reported for each of the six species, drawn directly from the primary studies discussed above. Table 2 presents a qualitative comparison of the major phytochemical classes detected by standard screening tests across the same species.

Table 1 (see in last page)

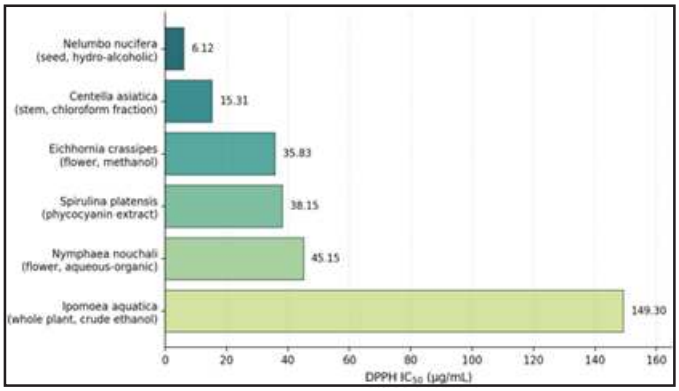


Figure 1: Comparative DPPH Radical-Scavenging Potency of Selected Aquatic Medicinal Plant Extracts

Figure 1 kind of compares the DPPH IC50 numbers (µg/mL) for the most potent extract or fraction that was reported in the referenced work, for each species. Basically, smaller values mean the extract had stronger radical scavenging. The plotted points come from six separate studies, and they used various plant parts , plus different solvents too (Nelumbonucifera seed extract: ScienceDirect, 2005; Centellaasiatica stem chloroform fraction: Clinical Phytoscience, 2023; Eichhorniacrassipes flower methanol extract: Pharmacognosy Journal, 2022; Spirulina platensis phycocyanin extract: ScienceDirect, 2025; Nymphaea nouchali flower extract: Scientific Reports, 2025; Ipomoea aquatica whole-plant crude ethanol extract: Aquaculture, Fish and Fisheries, 2022). Because the assays were done differently, these results really should not be treated as directly comparable.

Table 2 (see in last page)

The comparative data show a kind of broadly consistent pattern, species and extracts with higher reported phenolic and flavonoid content tend, though not fully every time, to come with lower (more potent) DPPH IC50 values, which supports the well-established structure–activity relationship between hydroxylated aromatic compounds and free-radical

scavenging capacity. The lotus seed extract and the Centellaasiatica chloroform fraction kind of stand out as the most potent radical scavengers among the extracts surveyed, both in the low tens of micrograms per millilitre range or even less, and they are comparable to or nearly matching the potency of standard antioxidants such as ascorbic acid and BHT used as positive controls in the same studies. Water spinach by contrast often returns weaker (higher) IC50 values across the studies reviewed, though that might partly be because it usually has a lower degree of extract concentration or the fact that crude extracts were used rather than fractionated ones. Spirulina platensis is a partial exception to the general phenolic–antioxidant correlation, because a lot of its measured antioxidant activity is tied to the phycobiliproteinphycocyanin instead of classical phenolic compounds, and this mechanistic detail is discussed further in Section 6.

Antioxidant Mechanisms of Action: The DPPH and ABTS assays that are used across the studies reviewed here they mostly work via two kind of closely linked mechanisms: hydrogen-atom transfer (HAT), where an antioxidant gives away a hydrogen atom in order to neutralise the radical, and single-electron transfer (SET), where instead an electron is donated, and then it is often followed by proton loss. Phenolic compounds are effective in both routes because their hydroxyl groups, especially when they sit on an aromatic ring with electron-donating substituents, are able to stabilise the phenoxyl radical that forms, thanks to resonance delocalisation. Flavonoids seem to stretch this ability even further, due to their usual three-ring layout; the number and location of hydroxyl groups matter a lot, and the presence of a catechol on the B-ring, is typically linked with stronger radical-scavenging power, which matches the higher activity that was noted in flavonoid-rich fractions like the Centellaasiatica chloroform extract mentioned earlier. Tannins, found across most of the species that were looked at, also support antioxidant activity through a hydroxyl-donating style mechanism, but they add protein- and metal-binding capacity on top of that, so this may be one reason why Nymphaea nouchali seed extract shows especially high tannin and antioxidant values. Alkaloids and terpenoidsaponins, even though they're present in several species, tend to contribute less straight to the radical-scavenging tests, and they are often connected more with other pharmacological effects; for example the wound-healing action often attributed to Centellaasiaticat-riterpenoidsaponins.

Spirulina platensis is a bit of a mechanistically different story. Its main antioxidant, phycocyanin, is a chromoprotein, with a bilin chromophore that is structurally linked to bile pigments. In this case the chromophore takes on free radicals via a mix of hydrogen donation and radical addition, rather than by the more straightforward phenolic mode that seems to dominate in the vascular plants reviewed here. That sort of structural divergence probably accounts for why Spirulina biomass extracts can look like they have comparatively modest phenolic content, and still, when phycocyanin is pulled out and purified the antioxidant effect becomes broadly similar to the stronger phenolic extracts reported for the other species.

Applications: Nutraceutical, Pharmaceutical and Aquaculture Relevance: The species reviewed here kind of have uses that reach way beyond what people usually think of as human phytomedicine. For example, Centellaasiatica extracts have already been put into topical wound care and skin-related products based on their triterpenoid plus antioxidant makeup, even if the exact choice of formulation varies. Meanwhile, Nelumbonucifera seed and leaf extracts have been examined for hepatoprotective roles and also anti-angiogenic effects, which fits with their noted antioxidant activity. Spirulina platensis is one of the most commercially advanced among the six, sold globally as a dietary supplement and more and more studied as a natural colourant, plus antioxidant additive, in cosmetic products especially when it is in a phycocyanin purified format.

Of particular relevance for a journal that leans into aquatic research and environmental studies, it's kind of interesting how several of the reviewed species have direct use, within aquaculture environments. Ipomoea aquatica was evaluated, as a bioactive ingredient in fish feed, with the idea that its polyphenol and flavonoid levels might counter oxidative stress and also bolster disease resistance in cultured fish, which is really practical given how oxidative stress from crowding, handling and water quality swings is a known headache in intensive aquaculture.

Algal biomass, including Spirulina, is also a fairly well established aquafeed additive, mainly because it combines strong protein content with antioxidant pigments. In parallel, growing algae alongside fish operations has been looked at too, as a way to promote nutrient recycling and help with water quality management in integrated aquaculture systems, there is often a rationale there about making the whole setup more self-contained. Water hyacinth, even though it is an invasive species that usually brings major ecological and economic harm in many freshwater areas, can still be seen as a kind of worked example for converting an environmental burden into a usable resource. This is because the antioxidant and antimicrobial phytochemical content has been demonstrated, so in a more controlled scenario it could be valorised via managed harvesting rather than treated only as waste biomass.

Challenges, Limitations and Future Directions: Some limitations keep showing up in the reviewed literature and they sort of make direct comparison between species hard, like not that clean. First, the extraction solvent, which plant part was used, the extract concentration units (for example per gram dry weight, or per gram extract, or even per hundred grams fresh weight) and the reference standards are different a lot from study to study. Sometimes, it's even

different within the same species, which pretty much accounts for a big more than tenfold span in reported IC50 values for one species such as Nelumbonucifera or Nymphaea nouchali. Second, most of the studies that were looked at use in vitro chemical assays, like DPPH and ABTS, which are kind of useful as an quick screening, but they do not always forecast in vivo antioxidant performance or bioavailability. And also, only a small number of the reviewed papers actually go further into animal tests or clinical validation.

Third, because many of the species reviewed do grow in open water bodies that may get hit by agricultural runoff, industrial discharge or urban wastewater, their phytochemical content and safety profile can be kinda influenced by local water quality, including the likelihood of heavy-metal, or other contaminant accumulation, especially with a hyperaccumulator species like Eichhorniacrassipes. This is a key practical point for any proposed use of wild-harvested aquatic plant material, for food, feed or pharmaceutical purposes, and it really supports the need for source-water testing alongside phytochemical characterisation in future work. Fourth, seasonal plus developmental shifts in phytochemical content have been noted even within a single species, like the month-to-month changes in proximate and phytochemical composition for Nymphaea nouchali flowers, suggesting harvest timing is something that future standardisation efforts will have to manage, carefully too.

Future research would do well with harmonised extraction and assay procedures, so that real cross-species and cross-study comparisons are possible, plus more frequent use of complementary assays (FRAP, ORAC, cellular antioxidant assays) next to DPPH and ABTS. There should also be more focus on in vivo confirmation, and toxicological profiling, particularly for species such as water hyacinth, where contamination risk from the environment is a realistic issue. For the aquaculture relevant species discussed in Section 7, controlled feeding trials that quantify impacts on fish growth performance, oxidative stress biomarkers, and disease resistance would back up the applied evidence much more, beyond the current mostly in vitro view.

Conclusion: The six aquatic and wetland connected species that were reviewed here, Nelumbonucifera, Eichhorniacrassipes, Ipomoea aquatica, Nymphaea nouchali, Centellaasiatica and Spirulina platensis collectively show that watery ecosystems can carry a phytochemically abundant and pharmacologically meaningful flora but it still stays a bit under-noticed in mainstream antioxidant research when compared with terrestrial medicinal plants. The published reports, pretty much always link a higher phenolic and flavonoid load to stronger radical scavenging effects across these species, though there is also a lot of variation, caused by which plant part is used, the extraction solvent chosen and, for Spirulina in particular, a different pigment driven antioxidant pathway. Beyond their known, and sometimes still emerging, contributions to human phytomedicine and nutraceuticals, a few of these species also feel quite practical for aquaculture and broader environmental care. This can be through functional feed ingredients, or as a way to turn invasive biomass into something valuable. Using that opportunity more fully will likely depend on future studies that standardise extraction and assay methods, consider the environmental plus safety issues that are unique to plant material grown in water, and then go past only in vitro screening, toward evidence that is both validated in vivo and supported at field scale.

References:-

1. Baehaki, A., et al. (2022). Phytochemical Analysis and Antioxidant Activity of Water Hyacinth Flowers (Eichhorniacrassipes) Extract. Pharmacognosy Journal, 14(6 Suppl).
2. Chemical and biochemical characterization of Ipomoea aquatica: genoprotective potential and inhibitory mechanism of its phytochemicals against á-amylase and á-glucosidase. (2023). Frontiers in Nutrition. PMC10772144.
3. Composition and antioxidant properties of water lily (Nymphaea nouchali) tuber and development of composite biscuits. (2024). ScienceDirect.
4. Detection of proximate, phytochemical compositions, phycocyanin and antioxidant activity of Arthrospira platensis (Spirulina). (2025). Taylor & Francis Online.
5. Evaluation of the Chemical Compounds and Antioxidant and Antimicrobial Activities of the Leaves of Eichhorniacrassipes (Water Hyacinth). (2021). Jundishapur Journal of Natural Pharmaceutical Products (Brieflands).
6. Green extraction and purification of phycocyanin from Spirulina platensis: Evaluation of its bioactivity and photoprotection. (2025). ScienceDirect.
7. Hydroalcoholic extract of Nelumbonucifera seeds promotes wound healing and increases tensile strength in rats. (2025). ScienceDirect.
8. Nutraceutical Prospects and Antioxidant Activity of White and Red Water Lily Stem Available in Bangladesh. (2022). Current Research in Nutrition and Food Science Journal.
9. Parimala, M., &Shoba, F. G. (2013). Phytochemical analysis and in vitro antioxidant activity of hydroalcoholic seed extract of Nymphaea nouchaliBurm. f. Asian Pacific Journal of Tropical Biomedicine, 3(11), 887–895.
10. Phytochemical Analysis and Antioxidant Activity of CentellaAsiatica Extracts: An Experimental and Theoretical Investigation of Flavonoids. (2023). MDPI Plants, 12(20), 3547.
11. Phytochemical investigation and determination of phytoconstituents in flower extract of Nelumbonucifera.

(2019). Journal of Drug Delivery and Therapeutics, 9(1), 146–149.
12. Profiling of bioactive compounds and antioxidant activity of aquatic weed Ipomoea aquatica. Roy, S., et al. (2022). Aquaculture, Fish and Fisheries, Wiley Online Library.
13. Recent updates on the pharmacological and nutritional properties of Spirulina platensis: A comprehensive review. (2026). ScienceDirect.
14. Sivarajan, N. D., et al. Anti-Angiogenic Effect of Nelumbonucifera Leaf Extracts in Human Umbilical Vein Endothelial Cells with Antioxidant Potential. PMC4340789.
15. Stability and Antioxidant Activity of Food-Grade Phycocyanin Isolated from Spirulina platensis. ResearchGate.
16. Chandrika, U. G., et al. Antioxidant, cytotoxic, antibacterial and thrombolytic activities of Centellaasiatica L.: possible role of phenolics and flavonoids. (2023). Clinical Phytoscience, Springer Nature Link.
17. Antioxidant activity of Centellaasiatica: Effect of extraction solvent polarity. (2019). ResearchGate.
18. Antioxidant and Cytotoxic Activities of Centellaasiatica (L) Urb. (2009). International Journal of Molecular Sciences, 10(9), 3713.
19. Antioxidant activity of Nelumbonucifera (sacred lotus) seeds. (2005). ScienceDirect.
20. Antioxidant activity of Indonesian water spinach and land spinach (Ipomoea aquatica): A comparative study. (2019). IOP Conference Series.
21. Comparative Study of Antioxidant Activities of the Leaves and Stem of Ipomoea aquaticaForsk (Water Spinach). ResearchGate.
22. Comparative Study on Antioxidant Activities, Total Phenolic Compound and Pigment Contents of Tropical Spirulina platensis, Gracilariaarcuata and Ulva lactuca Extracted in Different Solvents Polarity. (2020). ResearchGate.
23. Enhancing the quality and antioxidant capacity of phycocyanin extracted from Spirulina platensis PCC 7345: A quality-by-design approach. (2024). ScienceDirect.
24. PHYTOCHEMICAL ANALYSIS OF LOTUS (NELUMBO NUCIFERA) rhizomes in Joto Reservoir, East Java, Indonesia. (2025). SABRAO Journal of Breeding and Genetics, 57(5), 2127–2138.
25. Antioxidant and Anticancer Activity of Spirulina platensis Water Extracts. International Journal of Pharmacology, 11(7), 846–851. (2015).
26. Antioxidant and Cytotoxic Effects of the Methanolic Extract of Eichhorniacrassipes Petioles Upon Mg-63 Cell Lines: An In Vitro Study. PMC10234613.
27. Tyagi, T., & Agarwal, M. (2017). Antioxidant Properties and Phenolic Compounds in Methanolic Extracts of Eichhorniacrassipes. Research Journal of Phytochemistry, 11, 85–89.
28. Unravelling Egyptian blue Lily (Nymphaea nouchali) organs' metabolome via UHPLC/PDA/ESI-QTOF-MS and in relation to their antioxidant and anti-cholinesterase effects. (2025). Scientific Reports (Nature).
29. Water Lily (Nymphaea nouchaliBurm. f): An Ancient Treasure of Food and Medicine. ResearchGate.

Table 2. Qualitative phytochemical screening of selected aquatic medicinal plants (+ = detected; ± = detected in some studies or plant parts only; - = not detected).

Species	Alkaloids	Flavonoids	Tannins	Saponins	Phenols	Terpenoids/Steroids
Nelumbonucifera	+	+	+	+	+	+
Eichhorniacrassipes	-	+	+	+	+	+
Ipomoea aquatica	+	+	+	±	+	+
Nymphaea nouchali	+	+	+	+	+	+
Centellaasiatica	±	+	+	+	+	+
Spirulina platensis	-	+	±	-	+	±

Table 1. Comparative total phenolic content (TPC), total flavonoid content (TFC) and DPPH radical-scavenging IC50 values reported for selected aquatic medicinal plants.

Species	Plant part / extract	TPC (mg GAE/g)	TFC (mg QE or RE/g)	DPPH IC50	Source
Nelumbonucifera	Leaf, methanolic	147.63 ± 2.32*	41.86 ± 1.07*	514.36 µg/mL	Sivarajan et al., 2015, PMC4340789
Nelumbonucifera	Seed, hydro-alcoholic	7.61% w/w (TPC)	—	6.12 ± 0.41 µg/mL	ScienceDirect, 2005
Eichhorniacrassipes	Leaf, hydro-methanolic	491.2 ± 31.9	76.8 ± 7.8**	Not reported (AAE basis)	Brieflands JJNPP, 2021
Eichhorniacrassipes	Flower, methanol	Not reported	Not reported	35.83 ppm	Baehaki et al., Pharmacogn. J., 2022
Ipomoea aquatica	Whole plant, methanolic	142.43	43.06 (RE/g)	122 µg/mL (DPPH)	PMC10772144, 2023
Ipomoea aquatica	Crude extract (fish-feed study)	Not reported	Not reported	149.30 ± 1.43 µg/mL	Roy et al., 2022, Wiley AFF2.56
Nymphaea nouchali	Seed, hydro-alcoholic	179.56 ± 1.59 (GE/g)	23.55 ± 1.46 (QE/g)	42.82 µg/mL	Parimala& Shoba, 2013, PMC3793162
Nymphaea nouchali	Flower, aqueous-organic	Not reported	Not reported	45.15 µg/mL	Nature Sci. Rep., 2025
Centellaasiatica	Stem, chloroform fraction	155.46 ± 0.52	345.17 ± 1.12 (QE/g)	15.31 ± 0.32 µg/mL	Clin. Phytosci., 2023
Centellaasiatica	Leaf, aqueous	286 mg/100 g	36.1 mg/100 g	31.25 µg/mL	MDPI IJMS, 2009
Spirulina platensis	Dry biomass	40.45	Not reported	Not directly comparable (% basis)	IMR Press IJP, 2015
Spirulina platensis	Phycocyanin extract	Not applicable (pigment-protein)	Not applicable	38.15 ± 0.56 ppm	ScienceDirect, 2025

Reported per gram dry mass rather than per gram of crude extract.
Reported as flavonoid content in mg quercetin equivalents per gram dry weight. GAE = gallic acid equivalents; QE = quercetin equivalents; RE = rutin equivalents; AAE = ascorbic acid equivalents.

✻✻✻✻✻✻✻✻✻✻✻✻