Exploring Biodiversity and Monitoring Genetic Resources of Aquatic Plants in Manado, North Sulawesi, Indonesia

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Abstract. The diversity and abundance of aquatic plants in freshwater ecosystems are very important as supporting factors for ecosystems. Conservationists can help to preserve species from the threat of extinction. How can we support the most species of aquatic plants at minimum cost? One strategy is to search for them and identify biodiversity hotspots, especially where an exceptional concentration of endemic species is undergoing significant loss of habitat. The genetic resources of aquatic plants represent the health of aquatic environments, i.e. lakes, rivers and waterfalls. The erosion of these resources threatens the stability of inland water health. We examined the patterns, causes and implications of freshwater macrophyte richness and rarity in Manado. The provincial richness of all macrophyte species, including rare species, showed strong preferences for mesotrophic and eutrophic conditions. Meanwhile, the rare species occurring nationally were more evenly distributed across the entire gradient of trophic conditions. From the four survey locations in the waterfalls, lakes, and river flows of the Manado area, a total of 37 species of aquatic plants were collected. Each area surveyed included different species and this is unique to the Wallace region.

1. Introduction
According to Princetown University, New Jersey, aquatic plants are plants that grow partially or entirely in the water and whose roots grow in mud or float on water. According to [1], aquatic plants are plants that live around water and in water. According to [2], aquatic plants are plants that are submerged in stagnant or flowing fresh water. Many people, however, do not know about the types, benefits, or uses of aquatic plants for aesthetic beauty or for the balance of aquatic ecosystems. The main function of aquatic plants is as producers of energy production in aquatic ecosystems.

Plants are classified into 4 large groups based on their way of life: (1) algae these are aquatic plants that do not have complete organs; (2) thallus plants that float on water these are plants whose only leaves appear on the surface of the water, while other organs are in the water; (3) plants whose body is half on the water and half in the water (these are water plants whose leaves and half the body are on
the surface of the water, while half of the stem and the roots are in the water); and (4) submerged plants these are plants whose entire body is in the water or at the bottom of the water (Aquatic environments professional development continuing education course) [3].

Some of the benefits of aquatic plants are their function as ammonia removers, absorbers of water metal contamination, chelating agents, controllers of algae via the balancing of aquatic ecosystems, and as heavy metal controllers by acting as carbon sinks [3]. In the water, aquatic plants are used as indicators for the absorption of heavy metals. One example serving as evidence of high tolerance and absorption of high contamination used for metabolism is Typha angustifolia, which absorbs heavy metals in the presence of symptoms of necrosis and chlorosis. [4].

Several studies have proven the function of aquatic plants as inhibitors of algal growth. For example, [5] found asarone alpha phenolic acid compounds that play a role in reducing algal growth. In addition to this, aquatic plants have allelochemical compounds that are good for waters, such as Acarus gramineus, Aponogeton krauseanus, Bacopa maniera, Ceratophyllum demersum, Eichhornia crassipes, Eleocharis coloradensis, Eleocharis microcarpa, Eleocharis callitrichoides, Eleocharis canadensis, Eleocharis crispa, Eleocharis crisp, Eleocharis densa, Hottonia palustris, Lemma minor, Family Myriophyllum, Naphar lutea, Nymphaea capensis, Pistisia stratiotes, Posidonia oceanica, Potamogeton species, Potamogeton crispus, Sagittaria variabilis, Spartina alterniflora, Stratiotes aloides, Thalassia testudinum, Typha latifolia, Ulricularia vulgaris, Vallisneria americana, Vallisneria spiralis, Zostera nana, Zostera nana, and Zostera marina [6].

Photosynthesis in aquatic plants is different from land plants, because they face a high variation in CO₂ levels, ranging from 0-14 mg/l. Aquatic plants incorporate the strategy of carbon absorption and its reuse as energy [7]. Unlike terrestrial plants, aquatic plants do not have C3, C4, and CAM photosynthesis systems. Therefore, they can utilize a lot of bicarbonate found in alkaline water. The ability of aquatic plants to absorb bicarbonate in water can neutralize the pH of the water [8].

Investigating and identifying the endemism of Indonesian aquatic plants are vital steps in order to save ecosystems and recognize the available resources. The aim of our study, therefore, was to compile an inventory of aquatic plants in the lakes and waterfall areas of Manado, North Sulawesi.  

2. Materials and Methods

2.1. The study sites

The study sites were in four areas of North Sulawesi (Figure 1).
The names and coordinates of the study sites were:

- The river flow of Tunan waterfall (N 01°33'52.23 and E 12°58'28.13)
- Tunan waterfall (N 01°33'56.428’ and E 128°58’37.20)
- The plunge pool of Tunan waterfall (N 01°34’11.17 and E 224°58’43.76)
- Tuminperas waterfall in South Tomohon (N 01° 17’43.83 and E 124° 46’ 49.48)
- Lake Tondano (N 01°14’33.65” and E 124° 53’41.18”)
- Lake Linow (N 01°16’07.13’ and E 124°49’25.29”)

2.2. Census of Aquatic plants

All of the aquatic plants in the sampling study areas were tagged, and their coordinates recorded. Voucher specimens of censused aquatics plants at both sites were collected and identified at Herbarium Bogoriense, Botany Division, Research Centre for Biology Indonesian Institute of Science (LIPI) Cibinong Science Centre Indonesia. Where possible, specimens were identified to species level, or otherwise grouped into morphospecies. Photographic records were also taken for each aquatic plant.

3. Results

The study identified the differences in the richness, diversity, density and abundance of aquatic plants. A total of 38 species were recorded from six locations in the North Sulawesi sites. There were 18 species recorded at the Tunan waterfall Minahasa, 12 species were present at Lake Tondano, 6 species of aquatic plants were recorded in Tuminperas Waterfall, and just one species of aquatic plant was found in Lake Linow. This species is *Eleocharis dulcis* (Burm.f.) Trin. Ex Hensch. A total of 25 families were recorded from the six locations surveyed (Table 1).

### Table 1. List of aquatic plants species in Manado, North Sulawesi.

| No | Species Name          | Family         | Location                              | Photograph     |
|----|-----------------------|----------------|---------------------------------------|----------------|
| 1. | *Selaginella plana*   | Selaginellaceae| The plunge pool of Tunan waterfall    | ![Photograph](image1) |
|    | (Desv.ex Poir) Hieron |                |                                       |                |
| 2. | *Elatostema integrifolium* | Urticaceae    | Tunan Waterfall Minahasa              | ![Photograph](image2) |
|    | (D.Dom) Wedd          |                |                                       |                |
| 3. | *Mikania* sp          | Compositae     | The river flow of Tunan waterfall     | ![Photograph](image3) |
| 4. | *Calopogonium* sp     | Leguminoseae   | The river flow of Tunan waterfall     | ![Photograph](image4) |
| No | Species Name | Family        | Location                                      | Photograph |
|----|--------------|---------------|-----------------------------------------------|------------|
| 5  | *Ageratina* sp | Compositae    | The river flow of Tunan waterfall              | ![Ageratina sp](image1) |
| 6  | *Humata repens* (L.f.) J. Small ex Diels Syn Davallia repens (L.f.)Kuhn | Davalliaceae | Tunan Water fall Minahasa and The plunge pool of Tunan waterfall | ![Humata repens](image2) |
| 7  | *Commelina diffusa* Burm. F. | Commelinaceae | The river flow of Tunan waterfall and The plunge pool of Tunan waterfall | ![Commelina diffusa](image3) |
| 8  | *Ischaemum timorense* Kunth | Commelinaceae | The river flow of Tunan waterfall and The plunge pool of Tunan waterfall | ![Ischaemum timorense](image4) |
| 9  | *Begonia* sp | Begoniaceae   | Tunan Water fall Minahasa                      | ![Begonia sp](image5) |
| 10 | *Dischidia* sp | Apocynaceae   | The river flow of Tunan waterfall and The plunge pool of Tunan waterfall | ![Dischidia sp](image6) |
| 11 | *Pollia thyrsiflora* (Blume) Steud | Commelinaceae | Tunan Water fall Minahasa                      | ![Pollia thyrsiflora](image7) |
| 12 | *Schismatoglottis calyptrate* (Roxb) Zol.& Moritzi | Araceae | The river flow of Tunan waterfall              | ![Schismatoglottis calyptrate](image8) |
| 13 | *Dischidia punctate* (Blume) Decne | Apocynaceae | The river flow of Tunan waterfall and The plunge pool of Tunan waterfall | ![Dischidia punctate](image9) |
| 14 | *Donax canniformis* (G.Forst.) K.Schum | Marantaceae | The river flow of Tunan waterfall              | ![Donax canniformis](image10) |
| No | Species Name | Family          | Location                  | Photograph |
|----|--------------|----------------|---------------------------|------------|
| 15 | Rhaphidophora sp | Araceae        | Tunan Waterfall Minahasa   | ![Image](image1.png) |
| 16 | Aglaonema simplex (Blume) Blume | Araceae        | The river flow of Tunan waterfall | ![Image](image2.png) |
| 17 | Ficus variegata Blume | Moraceae       | The river flow of Tunan waterfall | ![Image](image3.png) |
| 18 | Centotheca lappacea (L.) Desv. | Poaceae        | The river flow of Tunan waterfall | ![Image](image4.png) |
| 19 | Eleocharis dulcis (Burm.f.) Trin. Ex Hensch | Cyperaceae   | Lake Linow Tomohon         | ![Image](image5.png) |
| 20 | Amphineuron sp | Thelypteridaceae | Lake Tondano Minahasa     | ![Image](image6.png) |
| 21 | Hymenachne amplexicaulis (Rudge) Nees | Poaceae        | Lake Tondano Minahasa      | ![Image](image7.png) |
| 22 | Cyperus odoratus L | Cyperaceae   | Lake Tondano Minahasa      | ![Image](image8.png) |
| 23 | Ludwigia adscendens (L) H.Hara | Onagraceae    | Lake Tondano Minahasa      | ![Image](image9.png) |
| 24 | Pistia stratiotes L | Araceae        | Lake Tondano Minahasa      | ![Image](image10.png) |
| 25 | Eichhornia crassipes (Mart.) Solms | Pontederiaceae | Lake Tondano Minahasa      | ![Image](image11.png) |
| No | Species Name                  | Family         | Location               | Photograph |
|----|------------------------------|----------------|------------------------|------------|
| 26 | *Limnocharis flava* (L.) Buchenau | Alismataceae   | Lake Tondano Minahasa  | ![Image](image1) |
| 27 | *Eclipta prostrata* (L.) L. | Compositae     | Lake Tondano Minahasa  | ![Image](image2) |
| 28 | *Neoachmandra leucocarpa* (Blume) | Cucurbitaceae  | Lake Tondano Minahasa  | ![Image](image3) |
| 29 | *Erechtites hieracifolia* (L.) Raf | Compositae     | Lake Tondano Minahasa  | ![Image](image4) |
| 30 | *Hydrilla verticillate* (L.f.) Royle | Hydrocharitaceae | Lake Tondano Minahasa  | ![Image](image5) |
| 31 | *Azolla* sp                  | Salviniaeae    | Lake Tondano Minahasa  | ![Image](image6) |
| 32 | *Ipomea aquatica*            | Convolvulaceae | Lake Tondano Minahasa  | ![Image](image7) |
| 33 | *Elatostema Strigosum* Hassk | Urticaceae     | Tuminperas waterfall in South Tomohon | ![Image](image8) |
| 34 | *Epithema benthamii* C.B.Clarke | Gesneriaceae   | Tuminperas waterfall in South Tomohon | ![Image](image9) |
| 35 | *Schismatoglottis calyptrate* (Roxb) Zoll & Moritzi | Araceae        | Tuminperas waterfall in South Tomohon | ![Image](image10) |
| 36 | *Adiantum diaphanum* Blume    | Pteridaceae    | Tuminperas waterfall in South Tomohon | ![Image](image11) |
4. Discussion

*Eleocharis dulcis* (Burm.f.) Trin. Ex Hensch, also known as the Chinese water chestnut (CWC), is of particular importance in this article because of its existence as the only aquatic plant that lives in the Lake Linow area. Lake Linow is a volcanic lake located outside Tomohon, near Manado, Indonesia. Several hydrothermal holes emit hot gases from the edges and floor of the lake. The shifting chemical composition of the lake means that the water often changes colours, ranging from red, to dark green, to dark blue.

The existence of *E. dulcis* as the only water plant in Lake Linow reinforces its ability to absorb heavy metals. The results of the study by [9] show that the stem, rhizome, and tap root of *E. dulcis* can absorb uranium, while the accumulation of uranium 30 in the root portion is 30 times higher than that in the stem. Water plants are suitable as filters in wetlands, displaying very high absorption rates in the roots and stems. The presence of *E. dulcis*, as the only aquatic plant that lives in Lake Linow, proves that it can survive in waters with heavy metals. Besides that, the stem of *E. dulcis* in Lake Linow is a nest/home for dragonflies the place where dragonflies lay eggs and mate. In addition, tubers from CWC can be consumed because they have high ferulic acid and polysaccharide compounds [10].

*E. dulcis* CWC contains less galactose but more arabinose and glucuronic acid and far more xylose than potatoes do. CWC contains less galacturonic acid than jicamas and potatoes, and this is confirmed by the extraction of pectin in various conditions and the stability at hot temperatures [11]. Since *E. dulcis* is stable in heat, it enables this aquatic plant to live in Lake Linow, in the presence of geothermal activity.

At Tunan waterfall we found *Begonia, sp*. This species is endemic to West Papua, Sulawesi and Molucca Island [12,13]. *Begonia, sp* lives on moist rock surfaces, including limestone substrates, vertical moist rock surfaces, and shady places in half to full shade at 600 m altitude. The endemic exotic aquatic plant of Lake Tondano is *Neoachmandra leucocarpa* (Blume) from the family *Cucurbitaceae*, which is found on the edge of the water body of Lake Tondano, Minahasa. The taste of this water cucumber is like land cucumber, although the aquatic variety exhibits a much smaller size of 5 cm (Figure 2).

![Figure 2. Neoachmandra leucocarpa (Blume), species endemic to Lake Tondano.](image-url)
5. Conclusion

Overall, the results of this study show that there are many endemic aquatic plants in the waterfalls, rivers and lakes of North Sulawesi. Each of the lakes and waterfall habitats has unique aquatic plants. This uniqueness indicates that the biodiversity in the North Sulawesi region is very high. Each aquatic ecosystem has its own characteristics, such as Lake Linow, which has only one species of aquatic plant.

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