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Introduce invasive alien macrophytes species in Indonesia national priority lakes (study case: lake Rawa Pening, Sentarum, Tempe, Tondano, Sentani)

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Abstract. According to Presidential Regulation (Perpres) Number 60 of 2021, 15 lakes are classified as Indonesia's national priority lakes. From 15 lakes, five of them are Tempe (South Sulawesi), Sentarum (West Kalimantan), Rawa Pening (Central Java), Tondano (North Sulawesi) and Sentani (Papua). Aquatic macrophytes are aquatic photosynthetic organisms that can be seen with the naked eye and actively grow periodically or permanently beneath, on, or above the water's surface. The national priority lakes face upon invasive aquatic macrophytes. Therefore, their presence must be controlled. This research purposed to introduce invasive aquatic macrophytes in several of Indonesia's national priority lakes. The aquatic macrophytes are recorded using a purposive sampling method with plots square (1x1 m²) and three replications. All aquatic macrophytes were documented, including species, family, population numbers, life forms and origin. The research from these five national priority lakes discovered a total of 10 families and 14 species of invasive aquatic macrophytes. The families were Pontederiaceae, Onagraceae, Polygonaceae, Lentibulariaceae, Araceae, Cyperaceae, Poaceae, Schropulariaceae, Alismataceae, Salviniaceae, and Hydrocharitaceae. The invasive aquatic macrophytes such as *Monochoria hastata*, *Eichhornia crassipes*, *Persicaria barbata*, *Ludwigia adscendens*, *Utricularia aurea*, *Ludwigia perennis*, *Pistia stratiotes*, *Ludwigia peruviana*, *Cyperus odoratus*, *Panicum repens*, *Bacopa floribunda*, *Limnocharis flava*, *Salvinia natans*, and *Hydrilla verticillata*. The research result can be used as guidelines for good lakes management.

Keywords: priority lakes; conservation; aquatic macrophytes; invasive

1. Introduction

Indonesia is a country that has high biodiversity. One of them is the aquatic macrophytes diversity in Indonesian lake waters. Indonesian lakes are different in their biodiversity, ecosystems, morphogenesis, morphology, and socio-economic conditions [1]. Aquatic macrophytes are aquatic photosynthetic organisms that can be seen with the naked eye and actively grow periodically or permanently beneath, on, or above the water's surface [2]. Aquatic macrophytes are represented in seven divisions: includes macroalgae of the divisions Chlorophyta (green), Xanthophyta (yellow-green), Rhodophyta (red), Cyanobacteria (blue-green), Pteridophyta (ferns), Bryophyta (mosses and liverworts), and Spermatophyta (seed-bearing) [2].

According to Presidential Regulation (Perpres) Number 60 of 2021, 15 lakes are classified as national priority lakes in Indonesia. From 15 lakes, five of them are Tempe (South Sulawesi Province), Sentarum (West Kalimantan Province), Rawa Pening (Central Java Province), Tondano (North Sulawesi Province)



and Sentani (Papua Province). However, one of the major issues in lake waters today is the presence of invasive alien species (IAS). IAS are plants that live outside their natural distribution and have the ability to invade areas so that other plants cannot grow well [3]. Also, IAS is a species that is introduced either intentionally or unintentionally from outside its natural habitat, which can live in its new habitat and poses a threat to biodiversity, ecosystem, socio-economic, and human health at the ecosystem, individual and genetic level [4]. IAS is a combination of alien species and invasive species [4]. IAS are supplied to Indonesia for cultivation, botanical garden collection, as experimental plants or as other curiosities. These alien plant species may be beneficial or potentially invasive [5]. Invasive species can replace native species or change the habitat conditions so that native species cannot survive for long periods of time due to competition for limited resources [6]. IAS have a negative impact on the food web, reduce biodiversity and endanger native fish populations [7].

Research on invasive plant species in Indonesia has become one of the popular topics related to species diversity, ecology, control and utilization aspects [8,9,10]. This research aimed to identify and introduce invasive macrophytes alien species in several Indonesia national priority lakes. The research result can be used as guidelines for good lakes management.

2. Methods

2.1. Study sites

This study was carried out at several priority lakes in Indonesia, including Tempe, Rawa Pening, Sentarum, Tondano, and Sentani. Tempe lake is located in South Sulawesi province. The morphogenesis of this lake is floodplain lake. Central Java province is residence of Rawa Pening lake. This lake's morphogenesis is a shallow volcanic lake. Sentarum lake is located in West Kalimantan province. The morphogenesis of this lake is floodplain lake. North Sulawesi province is residence to Tondano lake. This lake's morphogenesis is a volcanic lake. Sentani lake is located in Papua province. The morphogenesis of this lake is a shallow volcanic lake. The problems of those lakes in the aquatic zone such as growth of aquatic macrophytes uncontrolled (water hyacinth), eutrophication, sedimentation, water pollution from domestic waste and aquaculture [1].

2.2. Sampling

The study sites in Indonesian priority lakes can be seen in Figure 1. The aquatic macrophytes are recorded using a purposive sampling method with plots square ($1 \times 1 \text{ m}^2$) and three replications. All aquatic macrophytes were documented, including species, family, population numbers, life forms, and origin. The samples could be identified on the location or in the laboratory. All samples of aquatic macrophytes were collected and preserved with alcohol 70%. The plant identification (species) was carried out in the research center for limnology and water resource, national research and innovation agency (BRIN).

The samples of aquatic macrophytes were identified using plant identification books. The identification books used such as Weeds of rice in Indonesia [11], Aquatic weeds of Southeast Asia [12], Checklist of Indonesian freshwater aquatic herbs [13], Aquatic plants [14], A practical field guide to weeds of rice in Asia [15], Freshwater plants of Papua New Guinea [16], and Flora [17].

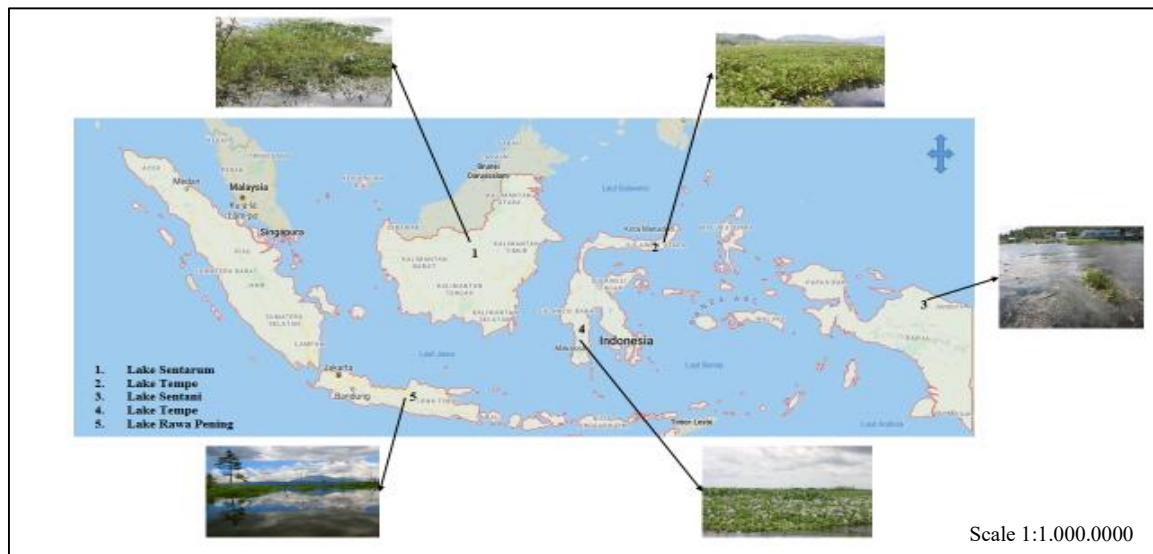


Figure 1. The study sites in Indonesian national priority lakes.

3. Result and discussion

3.1. Invasive alien macrophytes species

The research from these five national priority lakes discovered a total of 10 families and 14 species of invasive aquatic macrophytes (Table 1). The families were Pontederiaceae, Onagraceae, Polygonaceae, Lentibulariaceae, Araceae, Cyperaceae, Poaceae, Schropulariaceae, Alismataceae, Salviniaceae, and Hydrocharitaceae. Meanwhile, the invasive alien macrophytes species identified were *Monochoria hastata*, *Eichhornia crassipes*, *Persicaria barbata*, *Ludwigia adscendens*, *Pistia stratiotes*, *Ludwigia perennis*, *Utricularia aurea*, *Ludwigia peruviana*, *Bacopa floribunda*, *Cyperus odoratus*, *Salvinia natans*, *Panicum repens*, *Limnocharis flava* and *Hydrilla verticillata*.



Table 1. Invasive alien macrophytes species in Indonesian national priority lakes.





No	Species	Life Forms	Lakes				
			Sentarum	Tondano	Rawa Pening	Tempe	Sentani
1	<i>M. hastata</i>	Emergent	-	-	+	-	-
2	<i>E. crassipes</i>	Free Floating	+	+	+	+	+
3	<i>P. barbata</i>	Emergent	+	-	-	+	+
4	<i>L. adscendens</i>	Floating leaves	+	+	+	+	-
5	<i>P. stratiotes</i>	Free Floating	+	+	+	-	+
6	<i>L. perennis</i>	Emergent	-	-	+	-	-
7	<i>U. aurea</i>	Submersed	+	-	-	-	-
8	<i>L. peruviana</i>	Emergent	-	-	+	-	-
9	<i>B. floribunda</i>	Emergent	-	-	+	-	-
10	<i>C. odoratus</i>	Emergent	-	-	+	-	-
11	<i>S. natans</i>	Free Floating	-	-	+	-	-
12	<i>P. repens</i>	Emergent	-	-	-	+	-
13	<i>L. flava</i>	Emergent	-	+	+	-	-
14	<i>H. verticillata</i>	Submersed	-	+	-	-	+




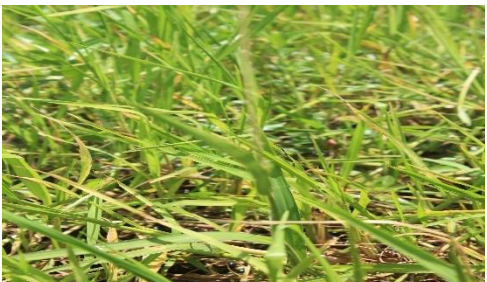
The research found ten species, five species, five species, four species and four species of invasive alien macrophytes on Rawa Pening, Sentarum, Tondano, Tempe, and Sentani lakes, respectively. The most frequent invasive alien macrophytes species were *Eichhornia crassipes* (found in all lakes), *Pistia stratiotes*, *Ludwigia adscendens* (found in 4 lakes), *Persicaria barbata* (found in 3 lakes) and *Limncharis flava*, *Hydrilla verticillata* (found in 2 lakes). The other species, however, were only found in one lake.





In Indonesia, important invasive alien plant are classified into two habitats: aquatic and terrestrial zone [5]. Indonesia's most important invasive aquatic plant species were *Mimosa pigra*, *Eichhornia crassipes*, *Hydrilla verticillata*, *Salvinia molesta* and *Pistia stratiotes* [18,19]. In Indonesia, there are estimated 1,936 alien plant species, that some of which have become invasive and have a negative impact on several ecosystems [20]. Invasive alien species include herbs, shrubs, grasses, trees, or aquatic plants and ferns. These alien species quickly established themselves in their new environment and spread rapidly, also suppressing native species [5] (Table 2).

Table 2. Invasive Alien Macrophytes Species (IAS) Description.

No	Species	IAS Description
1	 <p><i>Monochoria hastata</i> (L.) Solms</p>	<p><i>Synonims:</i> <i>M. chinensis</i>, <i>M. dilatata</i>, <i>M. hastifolia</i>, <i>M. sagittata</i> <i>Family:</i> Pontederiaceae <i>Origin:</i> Asia <i>English name:</i> Arrow leaf pondweed <i>Indonesian name:</i> Wewean <i>Distribution:</i> Asia, Malesia, N. Australia</p>
2	 <p><i>Eichhornia crassipes</i> (Mart) Solms</p>	<p><i>Synonims:</i> <i>E. crassicaulis</i>, <i>Pontederia crassipes</i>, <i>P. crassicaulis</i>, <i>P. elongata</i> <i>Family:</i> Pontederiaceae <i>Origin:</i> South America <i>English name:</i> Water hyacinth <i>Indonesian name:</i> Eceng gondok <i>Distribution:</i> warm temperate to rainforest zones, tropical to subtropical</p>

No	Species	IAS Description
3	 <i>Persicaria barbata</i> (L.) H. Hara	<i>Synonyms:</i> <i>P. omerostromia</i> , <i>Polygonum barbatum</i> , <i>P. kotoshoense</i> <i>Family:</i> Polygonaceae <i>Origin:</i> Asia or Africa <i>English name:</i> Knot grass <i>Indonesian name:</i> Jukut carang <i>Distribution:</i> Africa, Asia to Australia
4	 <i>Ludwigia adscendens</i> (L.) H. Hara	<i>Synonyms:</i> <i>Jussiaea adscendens</i> , <i>J. Fluviatilis</i> , <i>J. repens</i> <i>Family:</i> Onagraceae <i>Origin:</i> Asia <i>English name:</i> Water primrose <i>Indonesian name:</i> Krangking <i>Distribution:</i> Tropical continental S.E. Asia
5	 <i>Utricularia aurea</i> Lour.	<i>Synonyms:</i> <i>U. Blumei</i> , <i>U.confervifolia</i> , <i>U. pilosa</i> <i>Family:</i> Lentibulariaceae <i>Origin:</i> Asia <i>English name:</i> Golden or leafy bladderwort <i>Indonesian name:</i> Ganggang <i>Distribution:</i> Japan to Australia, India to China, throughout Malesia, throughout Indonesia
6	 <i>Ludwigia peruviana</i> (L.) H. Hara	<i>Synonyms:</i> <i>L. hirta</i> , <i>Jussiaea hirta</i> , <i>J. macrocarpa</i> , <i>O. hirta</i> <i>Family:</i> Onagraceae <i>Origin:</i> Trop America <i>English name:</i> Peruvian primrose <i>Indonesian name:</i> - <i>Distribution:</i> Now spread throughout Java and Sumatra

No	Species	IAS Description
7	 <p><i>Ludwigia perennis</i> L.</p>	<p><i>Synonims:</i> <i>L. gracilis</i>, <i>L. parviflora</i>, <i>L. multiflora</i>, <i>Jussiaea perennis</i>, <i>J. caryophyllea</i> <i>Family:</i> Onagraceae <i>Origin:</i> Unknown <i>English name:</i> - <i>Indonesian name:</i> - <i>Distribution:</i> In Indonesia as far as known in Sumatra, Java, Sulawesi</p>
8	 <p><i>Pistia stratiotes</i> L.</p>	<p><i>Synonims:</i> <i>P. commutata</i>, <i>P. obcordata</i>, <i>P. occidentalis</i>, <i>Zala asiatica</i> <i>Family:</i> Araceae <i>Origin:</i> South America or Africa <i>English name:</i> Water lettuce <i>Indonesian name:</i> Apu-apu <i>Distribution:</i> Everywhere in Indonesia, Pantropical, very widely distributed</p>
9	 <p><i>Cyperus odoratus</i> (L.)</p>	<p><i>Synonims:</i> <i>C. bracteolatus</i>, <i>C. ferax</i>, <i>C. fragilis</i>, <i>C. lenticularis</i> <i>Family:</i> Cyperaceae <i>Origin:</i> Unknown <i>English name:</i> Fragrant flatsedge <i>Indonesian name:</i> Rumput teki <i>Distribution:</i> Warmer regions of whole world, Throughtout Malesia, throughtout Indonesia</p>
10	 <p><i>Panicum repens</i> (L.)</p>	<p><i>Synonims:</i> <i>P. arenarium</i>, <i>P. chromatostigma</i>, <i>P. ischaemoides</i> <i>Family:</i> Poaceae <i>Origin:</i> Africa or Asia <i>English name:</i> Torpedo grass <i>Indonesian name:</i> - <i>Distribution:</i> Africa, India, Sri Lanka, Thailand, Burma, Malaysia, United States</p>

No	Species	IAS Description
11	 <p><i>Bacopa floribunda</i> (R.Br.)</p>	<p><i>Synonyms:</i> <i>B. pubescens</i>, <i>Bramia floribunda</i>, <i>Herpestis floribunda</i> <i>Family:</i> Schropulariaceae <i>Origin:</i> Asia <i>English name:</i> - <i>Indonesian name:</i> - <i>Distribution:</i> Throughout Indonesia</p>
12	 <p><i>Limnocharis flava</i> (L.) Buchenau</p>	<p><i>Synonyms:</i> <i>L. emarginatan</i>, <i>Alisma flavum</i>, <i>Damasonium flavum</i> <i>Family:</i> Alismataceae <i>Origin:</i> Tropical America <i>English name:</i> Yellow burr head <i>Indonesian name:</i> Genjer <i>Distribution:</i> Indonesia, Malaysia, Burma, Thailand, Sri Lanka</p>
13	 <p><i>Salvinia natans</i> (L.) All</p>	<p><i>Synonyms:</i> <i>Marsilea natans</i> <i>Family:</i> Salviniaceae <i>Origin:</i> Unknown <i>English name:</i> Floating fern <i>Indonesian name:</i> Rumput ganepo <i>Distribution:</i> SE Asia, Africa to C. Europe</p>
14	 <p><i>Hydrilla verticillata</i> (L.f.) Royle</p>	<p><i>Synonyms:</i> <i>H. polysperma</i>, <i>Elodea verticillata</i>, <i>Vallisneria verticillata</i> <i>Family:</i> Hydrocharitaceae <i>Origin:</i> Unknown <i>English name:</i> Waterthyme <i>Indonesian name:</i> Ganggang hijau <i>Distribution:</i> From South and East Europe, Africa, Asia, Australia</p>

3.2. The invasive alien macrophytes species origin

The invasive alien macrophytes species originated from almost every continent and region of the world (Asia, South America, Tropical America and Africa). The highest number came from Asia 35.30%, followed by unknown 23.53%, and Africa 17.65%. South America and Tropical America had the lowest number invasive alien macrophyte species, accounting for only 11.76% of the total (Figure 2).

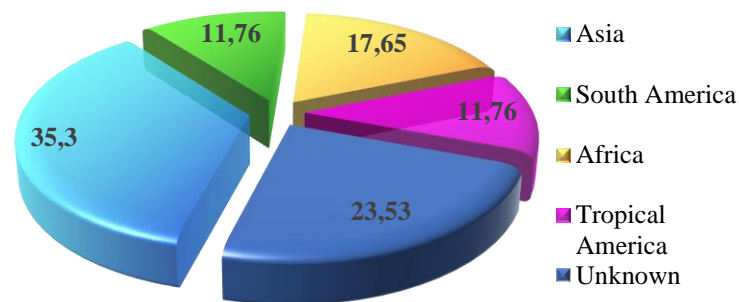


Figure 2. Origin percentage of the invasive alien macrophytes species.

4. Conclusion

The study results from five national priority lakes showed a total of 10 families and 14 species of invasive alien macrophytes. The invasive alien macrophytes such as *Eichhornia crassipes*, *Monochoria hastata*, *Ludwigia adscendens*, *Ludwigia perennis*, *Ludwigia peruviana*, *Persicaria barbata*, *Utricularia aurea*, *Pistia stratiotes*, *Cyperus odoratus*, *Panicum repens*, *Bacopa floribunda*, *Limncharis flava*, *Salvinia natans* and *Hydrilla verticillata*. The most invasive alien macrophytes were discovered in Rawa Pening lake (10 invasive species). *Eichhornia crassipes* was the most frequent invasive alien macrophyte species discovered (in all lakes). The origins of invasive alien macrophytes discovered are mostly from Asia.

Author statement

All authors had equal contributions to this study.

CRediT authorship contribution statement

Riky Kurniawan: Conceptualization, Resources, Data curation, Methodology, Investigation, Visualization, Writing - original draft. **Aiman Ibrahim:** Supervision, Writing - review & editing. **Eka Prihatinningtyas:** Supervision, Writing - review & editing. **Evi Susanti:** Supervision, Validation, Writing - review & editing. **Teguh Aditia Pratama:** Supervision, Writing - review & editing.

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