Invasive Aquatic Plant Species of Chenderoh Reservoir, Malaysia and Jatiluhur Reservoir, Indonesia

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Abstract. The sampling was carried out in two sampling sites; Chenderoh Reservoir, Malaysia and Jatiluhur Reservoir, Indonesia. These reservoirs are the initial of cascade reservoirs on Perak River and Citarum River. The aquatic plants distribution and abundance were recorded, and water quality parameters were measured. A total of 23 aquatic plant species from 14 families were identified. The populations of water hyacinth (Eichhornia crassipes) and giant salvinia (Salvinia molesta) were recorded in all sampling points of both reservoirs. Based on the TSI (Chl a), Chenderoh Reservoir was subjected to a mesotrophic, whereas, Jatiluhur Reservoir was subjected to an eutrophic reservoir. E. crassipes and S. molesta which were abundant in those reservoirs were listed in the 100 world worst invasive alien species.

1. Introduction
At present, 5% of aquatic plants found belong in the 100th of the world’s worst invasive alien species list [1], such as water hyacinth (Eichhornia crassipes), water fern (Salvinia molesta) and a few more to be named. These aquatic plant species could impede the fishing and water transportation activities by forming dense mats on the surface, clogging waterways, blocking out sunlight, and outcompete native floating plants for nutrients. Invasive alien species are regarded as the second largest threat to biodiversity after habitat loss. The special characteristic which makes these invasive alien species successfully invade a given area is the phenotype plasticity which is the ability to alter growth form to suit current condition [2,3].

The expanding global trade and cross boundaries activities allowed the transport of species to various parts of the world including Malaysia and Indonesia. These countries provide areas that are highly favoured by living organism to thrive and flourish in humid and warm tropical region. Some species are colonized and naturalized well to the local environment, while some become invasive. In Malaysia, aquatic plant species considered as noxious weeds are water hyacinth, Lemna and hydrlia, [4,5] and the most important species of invasive aquatic plants in Indonesia are water hyacinth, hydrlia, giant salvinia, giant mimosa and water lettuce [6,7]. These alien species easily established in this new environment, and spread so rapidly that native species were sometimes suppressed. This indicates that these plants possess a high degree of adaptation when accompanied with a lack of natural predators. Another characteristic of these plants is their rapid reproduction in both vegetative and generative states.
Annually, invasive species such as water hyacinth cost estimated USD $1.4 trillion worldwide [8,9]. The introduction would cause major threats to the native species as they often become subjected to great competition for resources, space, disease and many more. Updated data is required in order to effectively control and manage the spread of invasive species in the ASEAN region. Hence, this study was carried out to determine the distribution and ecology of invasive aquatic plant species in tropical reservoirs, with special reference to Chenderoh and Jatiluhur.

2. Materials and methods
The study was conducted at two sites, Chenderoh Reservoir, Malaysia (figure 1) and Jatiluhur Reservoir, Indonesia (figure 2). The first sampling was carried out in April 2017 at Chenderoh Reservoir and the second sampling was in April 2018 at Jatiluhur Reservoir. Three randomly selected sampling points were deployed in each reservoir for vegetation and water quality survey. The coordinate for each sampling points is shown in Table 1.

![Figure 1](image1.png)

**Figure 1.** Location of sampling points at Chenderoh Reservoir, Perak, Northern Region of Peninsular Malaysia.

The sampling points are located at the flooded area of the reservoirs except for X1 in Chenderoh Reservoir, which was located at the tributary of Perak River. The depth of each sampling points were recorded with the aid of a depth meter.

The data on aquatic plant distribution and abundance were gathered from a boat according to the surface inventory method [10]. A sampling rake 2.5 meters long was used to collect submerged plant samples. The plants were photographed and identified based on Pancho and Soerjani, 1978 [6]. Plant cover were estimated from the surface based on species presence at sampling points, with species occurrence of 0%-none, 1% to 25%-rare, 26% to 65%-moderate and 66% to 100%-abundant. The invasive species were referred to the IUCN checklist for their ranking in the 100 of the world’s worst invasive alien species [11].

The physico-chemical parameters of pH, DO and conductivity were measured in-situ by using portable meters and secchi depth was measured by using a secchi disc. Water samples at the surface
were collected with a Van Dorn water sampler and transferred into 500 ml polyethylene bottles. Each sampling point included two replicate samples that were stored in an ice box before transported back to USM Ecology Laboratory, Penang and Research Centre for Limnology Laboratory in LIPI, Indonesia.

Figure 2. Location of sampling points at Jatiluhur Reservoir, Purwakarta Regency, West Java Province, Indonesia.

Table 1. The coordinates of sampling points in Chenderoh Reservoir and Jatiluhur Reservoir.

| Sampling site  | Sampling point | Latitude            | Longitude                     | Depth (m) |
|----------------|----------------|---------------------|-------------------------------|-----------|
| Chenderoh      | X1             | 4°59'57.78" N      | 100°56'49.07" E              | 6         |
| Reservoir      | X2             | 4°58'40.79" N      | 100°56'56.79" E              | 3.7       |
|                | X3             | 4°57'50.56" N      | 100°56'43.14" E              | 4.8       |
| Jatiluhur      | Y1             | 6°33'02.80" S      | 107°23'29.81" E              | 35.4      |
| Reservoir      | Y2             | 6°31'31.10" S      | 107°21'59.23" E              | 54.2      |
|                | Y3             | 6°31'54.36" S      | 107°19'37.22" E              | 67.4      |

In the laboratory, analysis for Chlorophyll $a$ (Chl $a$; mg/L) and Total Suspended Solids (TSS; mg/L) was done based on Adams, 1990 [12]. Chlorophyll $a$ analysis was conducted by filtering 200 ml of water samples through a 0.45 µm Cellulose Nitrate Membrane filter paper. The pigment was extracted using 90% acetone and the optical densities were measured at 750 nm, 664 nm, 647 nm, and 630 nm. The results of Chlorophyll $a$ pigments were subjected to Carlson’s Trophic State Index (TSI) [13]. The total suspended solids were determined by filtering 250 ml of water samples through a 47 mm glass microfiber filter paper (GF/C). The TSS was analysed by the difference of weight before and after filtering and drying the GF/C filter paper.
3. Results and discussion
A total of 23 aquatic plant species were identified from the two reservoirs (Table 2). From the result, 21 species of aquatic plants from 14 families were recorded in Chenderoh Reservoir, while six species of aquatic plants from three families were recorded in Jatiluhur Reservoir.

Table 2. The list of aquatic plants species recorded in Chenderoh Reservoir, Malaysia and Jatiluhur Reservoir, Indonesia.

| Family          | Species                          | Class          | Chenderoh Reservoir | Jatiluhur Reservoir |
|-----------------|----------------------------------|----------------|---------------------|---------------------|
|                 |                                  |                | X1      | X2    | X3    | Y1     | Y2    | Y3    |
| Amaranthaceae   | *Alternanthera philoxeroides*    | Emergent       | *       | *     | *     | -      | -     | -     |
|                 | *Mart. Griseb*                   |                |         |       |       |        |       |       |
| Araceae         | *Colocasia esculenta* L. Schott | Emergent       | *       | *     | *     | -      | -     | -     |
|                 | *Lasia spinosa* L.               | Emergent       | *       | -     | *     | -      | -     | -     |
|                 | *Spirodela polyrrhiza* L. Schleid| Free-floating  | -       | *     | *     | **     | **    | **    |
|                 | *Lemma minor* L.                 | Free-floating  | *       | *     | *     | **     | **    | **    |
|                 | *Pistia stratiotes* L.           | Free-floating  | -       | *     | -     | -      | -     | -     |
| Ceratophyllaceae| *Ceratophyllum demersum* L.      | Submerged      | ***     | **    | ***   | -      | -     | -     |
| Convolvulaceae  | *Ipomoea aquatic* Forssk.        | Emergent       | **      | *     | *     | -      | -     | -     |
| Hydrocharitaceae| *Hydrilla verticillata* L.f Royle| Submerged      | **      | **    | **    | -      | -     | -     |
|                 | *Najas indica* Willd. Cham       | Submerged      | -       | *     | **    | -      | -     | -     |
|                 | *Ottelia alismoldes* L. Pers     | Submerged      | -       | *     | **    | -      | -     | -     |
| Leguminosae     | *Neptunia oleracea* Lour.        | Emergent       | ***     | *     | *     | -      | -     | -     |
| Lentibulariaceae| *Utricularia aurea* Lour.        | Submerged      | -       | *     | -     | -      | -     | -     |
| Nelumbonaceae   | *Nelumbo nucifera* Gaertn.       | Emergent       | -       | **    | ***   | -      | -     | -     |
| Onagraceae      | *Ludwigia hyssopifolia* G. Don   | Emergent       | *       | *     | *     | -      | -     | -     |
| Pandanaceae     | *Pandanus helicopus* Kurz.       | Emergent       | *       | ***   | ***   | -      | -     | -     |
| Poaceae         | *Bracharia mutica* Forssk.       | Emergent       | *       | **    | **    | -      | -     | -     |
|                 | *Phragmites australis* Cav. Trin | Emergent       | *       | *     | *     | -      | -     | -     |
|                 | *Saccharum spontaneum* L.        | Emergent       | *       | -     | *     | -      | -     | -     |
| Polygonaceae    | *Polygonum barbatum* L.          | Emergent       | *       | *     | **    | -      | -     | -     |
| Pontederiaceae  | *Eichhornia crassipes* Mart.     | Free-floating  | **      | *     | *     | ***    | ***   | ***   |
|                 | *Solms*                          |                |         |       |       |        |       |       |
| Salviiniaceae   | *Salvinia molesta* D.Mitch       | Free-floating  | *       | *     | **    | ***    | ***   | ***   |
|                 | *Azolla pinnata* R.Br            | Free-floating  | -       | -     | -     | **     | **    | **    |

Note: -: none, *: rare, **: moderate, ***: abundant
The most abundant species recorded were *Eichhornia crassipes*, *Salvinia molesta*, *Ceratophyllum demersum*, *Nelumbo nucifera*, *Neptunia oleracea* and *Pandanus helicopus* (plate 1).

Plate 1. Invasive aquatic plant species of Chenderoh Reservoir and Jatiluhur Reservoir. Note: 
A- *Eichhornia crassipes*  B- *Salvinia molesta*  C- *Ceratophyllum demersum*  D- *Nelumbo nucifera*  E- *Neptunia oleracea*  F- *Pandanus helicopus*

Based on recorded species found in both reservoirs, *Eichhornia crassipes* and *Salvinia molesta* were listed in the 100 world worst invasive alien species [11]. *E. crassipes* and *S. molesta* are alien to South East Asian countries. These two species originated from South America and south-eastern
Brazil respectively. The introduction of floating species is known to have shading effects on the underlying ecosystem [14]. In Chenderoh and Jatiluhur, water hyacinth and salvinia can be found in all sampling points. The water hyacinth and salvinia was relatively high in abundance at Jatiluhur Reservoir (plate 2).

Plate 2. Water hyacinth (*Eichhornia crassipes*) population was recorded on the surface of Jatiluhur Reservoir, Indonesia.

The uppermost reservoir on Citarum River is Saguling Reservoir. This reservoir is highly polluted with domestic and industrial effluent from the urban areas of Bandung. The reservoir experiences major water quality problems, including excessive growths of floating plants particularly water hyacinth [15]. Water hyacinth is a very fast growing plant, with populations known to double in as little as 12 days [16]. This species creates shading, and crowding of native aquatic plants which dramatically reduces biological diversity in aquatic ecosystems. It still remains as the world’s most problematic water weed despite widespread and various approaches to its control [17]. Soerjani *et al.* [18] rated the floating weed species, *E. crassipes* and *S. molesta* among the most noxious in Southeast Asia. They also singled out *E. crassipes* as the most problematic aquatic weed in Southeast Asia. In fact, works on *E. crassipes* in Southeast Asia including Malaysia are well documented [5,19,20,21,22].

In Chenderoh Reservoir, emergent and submersed aquatic plants dominated the sampling area. *Ceratophyllum demersum*, *Nelumbo nucifera*, *Neptunia oleracea* and *Pandanus helicopus* were the most abundant aquatic plant species in Chenderoh. *Hydrilla verticillata* was found to have been moderately distributed in all sampling points at Chenderoh. Two of the species, hydrilla (*H. verticillata*) and coontail (*C. demersum*) are considered as noxious weeds. Although they are considered as weeds, these two species however are being utilized as aquarium plants [4].

The concentration of dissolved solids will affect water conditions especially on the penetration of sunlight into the water. The sunlight penetration into water bodies will be shorter with high content of dissolved solids. This will affect the productivity of phytoplankton that are very dependent on sunlight. Table 3 shows the water quality for Chenderoh Reservoir (x) and Jatiluhur Reservoir (y).
Table 3. Results of water quality analysis at Chenderoh Reservoir, Malaysia and Jatiluhur Reservoir, Indonesia.

| Sampling points | SD (m) | DO [mg/l] | pH   | Cond. [mS/cm] | TSS (mg/L) | TSI(Chl a) |
|-----------------|--------|-----------|------|---------------|------------|------------|
| X1              | 117.5  | 6.45      | 6.73 | 0.022         | 0.0097     | 48.0       |
| X2              | 37.5   | 7.93      | 6.33 | 0.472         | 0.0132     | 41.7       |
| X3              | 135.5  | 7.66      | 6.32 | 0.414         | 0.00      | 36.3       |
| Y1              | 116    | 8.07      | 5.8  | 0.24          | 0.0016     | 68.6       |
| Y2              | 115    | 9.87      | 6.1  | 0.23          | 0.0014     | 65.3       |
| Y3              | 112.5  | 8.15      | 5.7  | 0.23          | 0.0010     | 62.4       |

The degradation of environment, including in water quality of reservoir occurred in the sampling areas. Anthropogenic activities contributed to the decrease of water quality. The growth of population influenced the activities of people in the surroundings of the reservoirs. Based on the results of Carlson’s TSI (Chl a) analysis, Chenderoh Reservoir can be considered as mesotrophic, whereas, Jatiluhur Reservoir can be considered as an eutrophic reservoir. The TSI (Chl a) in Chenderoh is in mesotrophic ranges (TSI 40-60) [23]. The trend of macrophyte problems were seen at Jatiluhur Reservoir due to excessive nutrient load. The excessive amount of toxic chemicals was being dumped into the Citarum River by industries and housing area. Not surprisingly, since 2008, nearly 60 percent of the river’s fish species have been destroyed. Citarum River is listed as the world’s most polluted river [24].

4. Conclusion

A few invasive aquatic plants species were identified at Chenderoh and Jatiluhur reservoirs. The species were free-floating, submerged and emergent plants. The differences of aquatic plant class distribution in these two reservoirs are related to the reservoir morphology and depth. Submerged and emergent species could be found in a shallow, flow through reservoir and free-floating species were found on the surface of lakes and reservoirs. The invasive species are thriving well due to favourable condition of water quality. The special phenotype plasticity characteristic supports the plants to be able to alter growth form to suit current condition.

5. References

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