

The Growth Rate of Water Hyacinth (*Eichhornia crassipes* (Mart.) Solms) in Rawapening Lake, Central Java

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ABSTRACT

Rawapening Lake is one of Indonesia's national priority lakes that is experiencing environmental problems which are urgently required to be solved due to its functions. The decline in the environmental quality of Rawapening Lake includes sedimentation, water pollution and excess of nutrients, especially Phosphorus (P) and Nitrogen (N) into the lake that induced uncontrolled growth of aquatic plants, one of which is water hyacinth (*Eichhornia crassipes* (Mart.) Solms). Many activities had been done to reduce the covering of water hyacinth in Rawapening Lake that tends to increase by the time, but no significant result has been achieved. Therefore, this research was conducted in order to study the growth rate of water hyacinth with mesocosm in Rawapening Lake as a baseline to develop suitable management. There were three different sites, namely: Site I in the floating net cage area (FNCA), Rowoboni Village, Site II in the natural area of Bejalen Village which is far from the aquaculture sites, and Site III in the upper reaches of the Tuntang river, Asinan Village. The research was performed in November – December 2019 with the measurements of growth rate, addition number clump and water hyacinth covering every week. The experiment was conducted in the 1 x 1 meter mesocosm, with three replication in every site. In every mesocosm water hyacinth with similar initial weight of 160 grams and number of leaves 6–7 strands were grown in the mesocosm. On day 7 (H7) the average wet weight of water hyacinth increased by 201%. In the fourth week (H28) the average wet weight of water hyacinth increased by 788% compared to the initial weight when planted. The highest relative growth rate (RGR) value of water hyacinth was at site III (7.26%/day), followed by Site I (7.03%/day), and Site II (6.40%/day), respectively. The doubling time (DT) value of water hyacinth at the site I was 9.9 day, site II – 10.8 day, and site III – 9.6 day. One clump of water hyacinth weighing 160 grams was able to cover 1 m² of mesocosm within 21 days. On the basis of these results, to manage water hyacinth blooms one has to consider its growth rate.

Keywords: Rawapening, *Eichhornia crassipes*, mesocosm, Relative Growth Rate, Doubling Time

INTRODUCTION

Global concerns about environmental sustainability have become the main focus of the Sustainable Development Goals (SDGs), which is a new agreement in place after the Millennium Development Goals (MDGs) agenda. SDGs are joint agreements including Indonesia in global development throughout the world for the 2015–2030 period (UNDP Indonesia, 2015).

In-line with SDGs, The National Medium Term Development Plan (RPJMN) for the period 2020–2024 is clearly stated in chapter 7, which is to build the environment, improve disaster resilience and climate change. More specifically focused on the maintenance, restoration and conservation of water resources and ecosystems through the revitalization of national priorities, namely 5 Lakes of Maninjau, Sentarum, Limboto, Sentani and Rawapening (Presidential Regulation No. 18, 2020).

Rawapening is semi-natural lake which is administratively located in the Semarang Regency, Central Java Province, it has inundation area of about 2,667 hectares in the rainy season and shrinks to 1,650 in the dry season (Sudjarwo et al., 2014). Lake Rawapening is utilized for fisheries, agriculture, tourism, social and religious life, as a source for drinking water and hydroelectricity (Soeprbowati, 2017). The production of aquaculture fish in the Rawapening area is 1,535.9 tons/year. Power plants that utilize Rawapening water bodies produced 222,504 million KWh. Irrigation around Rawapening Lake technically covers 1,265.09 hectares of rice fields. Since 2015, Rawapening Lake has also been used by the Semarang Regency Regional Water Supply Company to meet the shortage of source for drinking water (Central Java Governor Regulation No. 5 of 2014 concerning Water Designation and Tuntang River Water Management in Central Java Province).

Sustainable lake management is a commitment at the government level to save the lake from the environmental damage resulting from the exploration and exploitation of communities with an interest in lake waters. The form of commitment from the government is the establishment of 15 priority lakes that have experienced critical damage and become an environmental problem that must be resolved immediately (Soeprbowati, 2017). Environmental degradation of Rawapening Lake includes sedimentation, pollution inorganic waste materials, reduction of water quality and the occurrence of eutrophication. This condition is caused by the accumulation of various pollutants that enter the aquatic environment. The pollutants come from various sources, including urbanization, population growth rates that are in line with domestic waste disposal, and excessive use of fertilizers and pesticides in the agricultural sector (Haseena et al., 2017; Salam and Salwan, 2017; Ting et al., 2018). Eutrophication is an enrichment of lake by nutrients, especially phosphorus (P) and excessive nitrogen (N) that induced uncontrolled growth of aquatic plants (Grasset et al., 2016; Chander et al., 2018; Sutadian et al., 2018).

The growth of water hyacinth in Rawapening Lake is an important issue to study because its existence significantly affects the water conditions. The very fast growth of water hyacinths with relatively short life spans greatly affects the ecosystem and is a threat in various parts of the world,

especially tropical waters (Allo et al., 2013; Gai-kwad and Gavande, 2017). The abundance of water hyacinth is also a habitat for disease carriers such as the mosquito that causes malaria (Honlah et al., 2019). Dead hyacinth will settle to the bottom waters and decompose, which increases the acceleration of sedimentation in Rawapening Lake. Wind also affects the nutrient dynamics in the lake, causing water hyacinth to float into new areas and triggering sediment resuspension which increases the release of nutrients in the lake (Worqlul et al., 2020).

The organic materials triggering the blooming of hyacinth are, among others, N and P (Goshu et al., 2017). On the content of total N and total P, Rawapening Lake shows the state that is both hypertrophic (Pratiwi et al., 2018). However, based on the assessment of the chlorophyll a content of the Rawapening Lake waters, it is in an oligotrophic state. Most of the chlorophyll content in waters comes from phytoplankton. Phytoplankton is not able to compete because it is shaded by the water hyacinth of Rawapening (Soeprbowati and Suedy, 2010).

The uncontrolled growth of water hyacinth often causes problems include clogging the drains and caused flooding (Kriticos and Brunel, 2016). Oxygen depletion and decreased water quality lead to reduced biodiversity and create a breeding ground for insects vector, increasing the rate of evapotranspiration, which in turn, impacted the public health (Kamau et al., 2015; Goshu and Aynalem., 2017; Gupta and Yadav, 2020;). The water hyacinth blooming is also often associated with a decrease in the number of fish because part of the water surface is covered by water hyacinth (Güereña et al., 2015).

It was reported that in 1994, Rawapening Lake was covered by a variety of aquatic plants which consisted of 18.45% water hyacinth, 7.69% *Hydrilla verticillata*, and 15.36% *Salvinia sp* (Goltenboth and Timothy 1994). In 2004, the covering of water hyacinth was 60–70%. In 2015, the amount of water hyacinth weed cover has reached more than 70% (Soeprbowati et al., 2016). In their research, Hidayati et al. (2018) showed that the area of aquatic plants in 2012 was 775.49 ha, while in 2016 it increased to 990.53 ha. Therefore, the covering of aquatic plants increased from 46% to 58%. Currently, the water hyacinth cover has returned to more than 70%. This indicates that the handling of environmental pollution in Rawapening Lake does not reduce the problematic roots.

The main factors that reduce the water quality in Rawapening Lake, which triggers the growth of water hyacinth, are phosphate, temperature and carbonate (Soeprbowati et al., 2016). The control of water hyacinth growth is difficult due to the extremely rapid pace of weed growth and its ability to deposit the seed scattered by the flood (Júnior and Carvalho, 2019). The water hyacinth seeds have the ability to dormancy for up to 15 years, a potential ability to reproduce in a sustainable manner (Ojo et al., 2019).

One of the efforts made by the government to restore the Rawapening Lake ecosystem was to launch the Rawapening Lake Conservation Movement (Gerakan Penyelamatan Danau, named as GERMADAN) in 2011, followed by Lake Management Plan (Rencana Pengelolaan = RP Danau) 2019. The program is a reference for relevant agencies when running the Rawapening Lake conservation program. The controlling growth rate of water hyacinth becomes the first super priority program in GERMADAN and RP Rawapening. This program is also fully supported by the Pemali Juwana River Basin Agency (BBWS), which takes the role as a program leader. This super priority program is also supported by the Department of Maritime Affairs and Fisheries in Central Java and the Ministry of Environment (RP Danau Rawapening, 2019). Mechanical harvesting of water hyacinth has also been carried out by people around Rawapening Lake, who use it as souvenirs, animal feed and fertilizer. Every year, the government, through the relevant institution, has also taken action to collect water hyacinth from a water body.

All the efforts that have been made are apparently still not able to control the growth of water hyacinth. This related to the water hyacinth growth. In India, one water hyacinth plant will double within 14 days, and cover 1 m² within 52 days (Guitierrez et al., 2001). On the basis of the research developed by Soeprbowati (2017), one water hyacinth plant covered 1 m² within 22 days. Therefore, this research is important to provide the data on the growth rate of water hyacinth in Rawapening Lake that will be used a basis for the development of suitable management for Rawapening Lake.

MATERIALS AND METHODS

Study area

Rawapening is a semi-natural lake which is located about 45 kilometers south of Semarang City and 9 kilometers northwest of Salatiga City (Figure 1). Rawapening is in the golden triangle between Semarang, Solo and Yogyakarta. The coordinates are located at 7°04'–7°30' south latitude and 110°24'46'–110°49'06'' east longitude, and is at an altitude of 460 meters above sea level. Determination of the research location used the random sampling method based on the activities that influence the growth of *E. crassipes*. The research location was divided into three sites : Site I in the floating net cage area (FNCA), Rowoboni Village (7°18'31''S 110°25'25''E) and Site II in the natural area of Bejalen Village, far from the aquaculture site (7°16'32.0''S 110°25'05.5''E). Site III is in the upper reaches of the Tuntang river, Asinan Village (7°16'04 ''S 110°26'50'' E) (Figure 1).

Sample collection

This research was conducted on November to December, 2019. The sample of *E. crassipes* for research were taken around Rawapening Lake, selected based on uniform morphology, namely 6–7 leaves and 160 gram wet weight when planted. The samples were planted on a 1 x 1 meter plot using nets and bamboo as a frame and stakes. The research was conducted using the mesocosm approach experiments conducted in-situ and under natural conditions at 2 sites, each site with 3 replication of mesocosms. The measurements of wet weight and covering water hyacinth was performed every week for four weeks. Figure 2 shows the growth of water hyacinth 3 sites within three weeks (H21).

Data analysis

Relative Growth Rate (RGR) and doubling time (DT) of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) are calculated based on biomass (Verma and Sivappa, 2017; Astuti and Indriatmoko, 2018).

$$RGR = (\ln MT2 - \ln MT1) / T \quad (1)$$

$$DT = \ln 2 / RGR \quad (2)$$

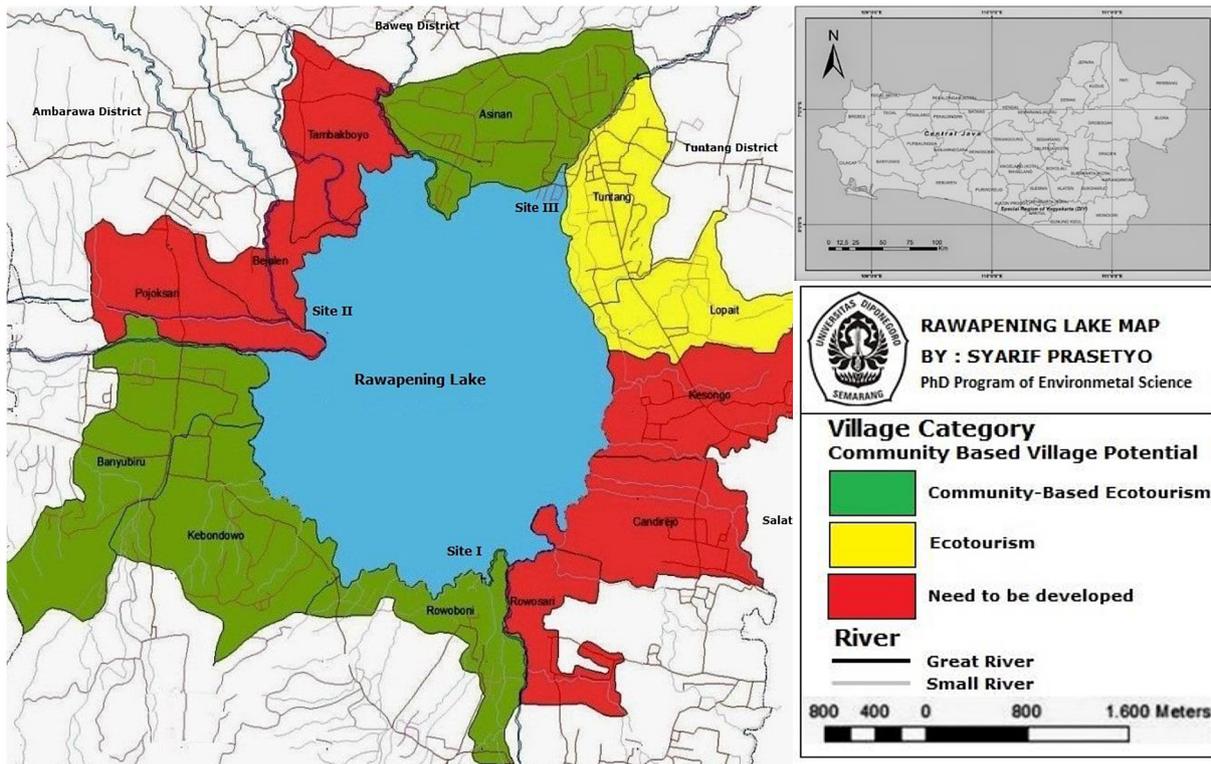


Figure 1. The location of research sites at Rawapening Lake, Central Java, Indonesia



Site I. in the floating net cage area Rowoboni Village

Site II in the natural area of Bejalen Village far from the aquaculture site

Site III is in the upper reaches of the Tuntang river, Asinan Village.

Figure 2. Water hyacinth growth within three weeks in 3 sites of Rawapening Lake

where: *RGR*: relative growth rate (grams/day)

T: Time

MT1: Biomass at the beginning of observation

MT2: Biomass at the end of observation

DT: Doubling Time (days)

The calculation is done from the first day of planting to the last measurement which is carried out on the twenty-eighth day. The hyacinth parameters observed in this study are the wet weight, increasing the number of clumps and covering.

RESULTS AND DISCUSSION

The rapid growth of water hyacinth in Rawapening Lake shows eutrophic conditions. On the basis of the results of this study, the sharp increase in wet weight more than doubled in one week. The wet weight of water hyacinth grown in the research plot was 160 grams. On day 7 (H7) the average wet weight of water hyacinths increased by 201%. In detail, at site I, the wet weight of water hyacinth increased by 208%, at site II by 191%, and at site III by 206%. In the fourth week (H28) the average wet weight of water hyacinth increased by 788% from the initial

weight when planted. In the fourth week (H28), the wet weight of water hyacinth at site I became 1.358 grams, increased from the initial planting weight of 849%. At site II it reached 722 grams, an increase of 451% from the initial planting weight, and at site III it amounted to 1700 grams or an increase of 1063% from the initial planting weight (Figure 3).

The increase in the number of water hyacinth clumps in each study site was directly proportional to the increase in the wet weight of the weeds. On the 7th day (H7), the average increase in the number of water hyacinth clumps was 4 clumps from 1 clump with 6–7 leaves during the first planting using mesocosm. The increase in the number of water hyacinth clumps at the site I was as many as 4 clumps, at site II – 3 clumps, and site III – 5 clumps. In the fourth week (H28), the average addition of water hyacinth clumps increased

by 14, with 13 clumps of site I, 9 clumps of site II, and 20 of site III (Figure 4).

The highest relative growth rate (RGR) of water hyacinth in Rawapening Lake was at site III (7.26%/day), followed by site I (7.03%/day) and the smallest was at site II (6.40%/day). RGR is a reflection of water hyacinth’s ability to absorb nutrients from water, apart from measuring the plant biomass. The RGR value of water hyacinth in Rawapening Lake is high compared to the RGR of water hyacinth in the Guadiana river valley of Spain, ranging from 4%-6% (Télliez 2008), in Bojong Soang Wastewater Treatment Plant, Bandung, West Java 0.069–0.072% (Sudjarwo et al., 2014) and Lake Toba which is only 4.21% (Siahaan et al., 2016). Likewise, when compared with the experiments conducted by Elella and Hassan (2016) on the growth rate of water hyacinth in the Egyptian irrigation network, which was only 0.11%/day.

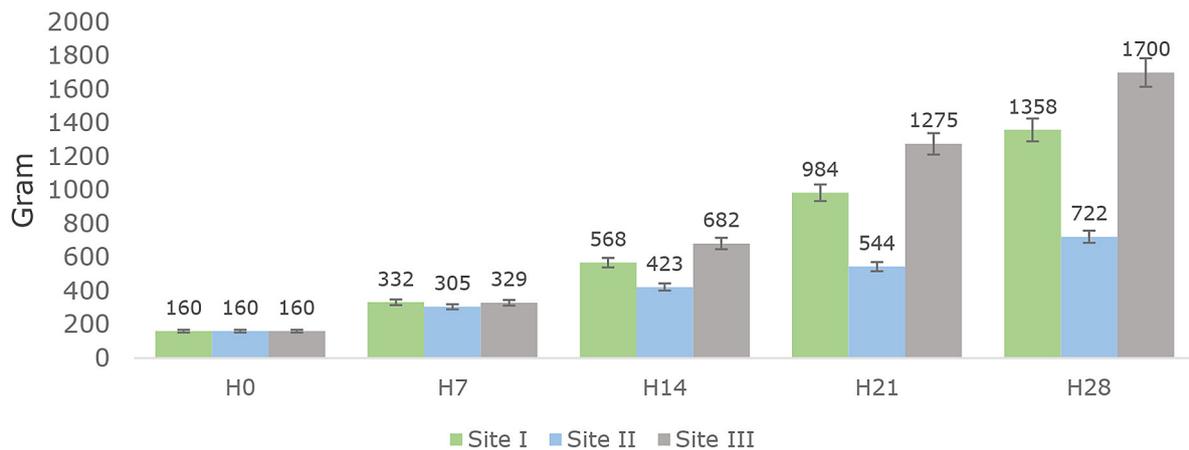


Figure 3. Biomass growth of water hyacinth in Rawapening Lake, Java

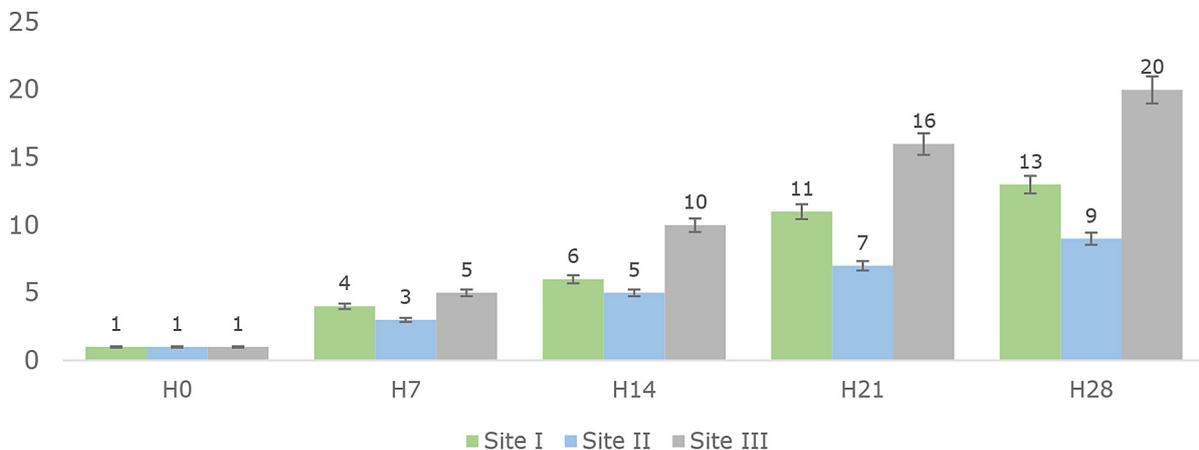


Figure 4. Number Clumps of water hyacinth in Rawapening Lake, Java

Doubling time (DT) is the time it takes the water hyacinth to double the existing number. The DT of water hyacinth at the site I was 9.9 day, site II – 10.8 day, and site III was 9.6 day. The DT capacity of Lake Rawapening water hyacinth is faster than in India, which takes 14 days (Gutierrez et al., 2001), on the Guadiana River which takes 10–60 days (Téllez 2008) and in Bojong Soang Bandung, West Java, which takes 9.7–10.5 days (Sudjarwo et al., 2014). The DT of Rawapening Lake water hyacinth was also lower than the water hyacinth in the Tu Liem district of Hanoi studied by Pham and Nguyen (2014), which took 18 days in summer and 28.5 days in autumn and winter. Likewise, it was lower when compared to the water hyacinth in Pesawaran Regency, Lampung Province, which requires a doubling time of 13.56 days (Haryanto et al., 2020).

RGR and DT water hyacinth have a relationship with changes in biomass or wet weight (Aswathy and Gopikuttan 2015). Figure 5 shows that the higher the wet weight, the greater the RGR value and the smaller the DT value. In H28, the water hyacinth grown in the experimental mesocosm at site III grew with the highest wet weight, 1700 grams. In site II, the water hyacinth grew with a weight of 1358 grams and the smallest in site III is 722 grams, all of which are grown from the water hyacinth seeds planted in H1, weighing 160 grams. Wet weight is also directly proportional to the number of clumps that are faster and fill the mesocosm area.

The cover of water hyacinth in each mesocosm was initially 4% and increased at H7, covering 32% of the Mesocosm Site I area and 29% of the Site II mesocosm area, and 37% of the Site III mesocosm area. At H14, after planting, water hyacinth had covered 70% of the mesocosm site I and 58% of the mesocosm site II and 76% of the mesocosm site III. At H21 mesocosm, site III was 100% covered with water hyacinth and at week

H28 mesocosm site I and site III were 100% covered with water hyacinth (Figure 5).

RGR, DT, clump growth and covering from each site are different because the nutrient factors at the study sites are also different. The nutrient levels that play an important role in encouraging the growth rate of water hyacinth in Rawapening Lake are P and N from the catchment area of Rawapening. The decay of water hyacinths and dead algae also increase the amount of organic matter at the bottom of the lake. Nutrients accumulate in the sediments released into lake water bodies due to temperature changes that cause thermal inversion and mixing of lake water (Verma and Sivappa, 2017). Nitrogen and phosphorus are essential nutrients the existence of which can limit the growth of major producers in most aquatic ecosystems (Guignard et al., 2017). The high concentration of total P and total N at a site I is an indication of excessive organic matter contamination from the floating net cage area (Table 1). Besides, the tourism activities that are growing rapidly around the site I contribute to the increasing levels of aquatic organic matter.

On the basis of the Total Phosphorus (TP) and Total Nitrogen (TN), Rawapening Lake is in the condition of eutrophic/hypereutrophic (Table 1) Apart from cultivation activities, the P levels come from household and agricultural waste that enter Rawapening Lake, this condition is exactly what happened in the Batujai Reservoir in Rahim and Soeprbowati's research (2019).

The input of nutrients in the waters, especially P and N act as an extrinsic trigger that affects the biological dynamics at the genome level to the ecosystem (Guinard et al., 2017). The presence of a higher P and N in site I, compared to site II and site III, has a greater influence on the process of photosynthesis, cell growth, metabolism, and water hyacinth protein synthesis (Chapin et al., 2011), which in turn, induced a sharp growth rate of water hyacinth.

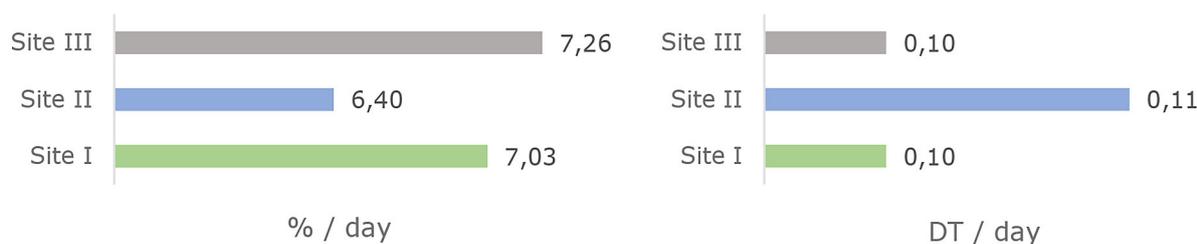


Figure 5. Relative Growth Rate (RGR) and Doubling Time (DT) of water hyacinth in Rawapening Lake, Java

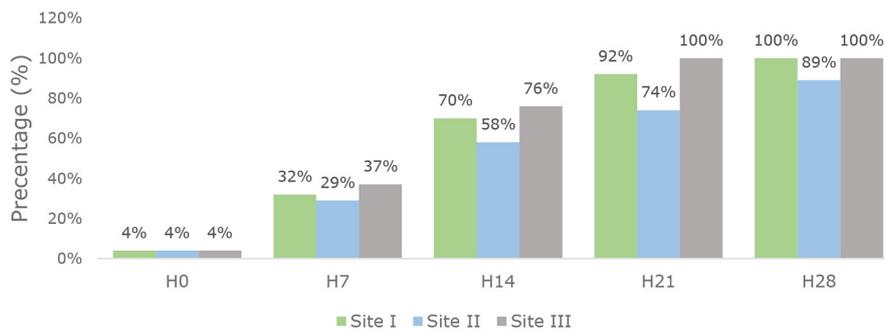


Figure 6. Water Hyacinth Covering in Rawapening Lake, Java

Many activities have been carried out to control the growth rate of water hyacinth in Rawapening Lake. Conventional and mechanical transportation by the community through community service is held every year. In January 2017, Operation and Control IV Rawapening unit (OP IV) was formed by the Pemali Juwana River Basin Agency (BBWSPJ) to handle Rawapening lakes. OP IV Rawapening use more adequate equipment such as excavator long arm (1 unit), excavator short arm (1 unit), multipurpose dredger (1 unit), amphibian weed harvester (3 units) and dump truck (3 units) (Figure 7). The equipment used has a capacity of 1 hectare/day. It is estimated that the operation of the equipment every day will be able to eliminate all the water hyacinth, assuming there is no vegetation that grows multiply. Mechanically managed lakes can work effectively in small areas, but large lakes such as Rawapening require more time, money and energy (Hidayati et al., 2018).

Three years after the OP IV Rawapening unit was formed, it turned out that the growth of water hyacinth was increasing. Mechanical handling is considered a failure because it does not consider the fundamental factors in the efforts to control the growth of water hyacinth. The study of Piranti et al. (2018) stated that the total phosphorus from the catchment area that enters Rawapening Lake is 10.32 mg/sec and 64.9% were settled in the sediment. These conditions

Table 1. The concentration (mg/L) of total P and total N in Rawapening Lake

Site	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
Site I	0.028	1.680
Site II	0.011	1.120
Site III	0.005	1.120

make Rawapening lake act as a total store of phosphorus and if the conditions are favorable, it will cause eutrophication which will fertilize the growth of water hyacinth.

The Government, through Central Java provincial agency of marine and fisheries, has also tried to reduce the water hyacinth using a biological agent. It involved as many as 5,000,000 grass carp fish (*Ctenopharyngodon idella*) to consume water hyacinth. The program was only realized by spreading of fish 100,000 in 2012, 105,000 in 2013 and 148,300 in 2014. In 2016 and so on, fish release was no longer carried out due to the application of Law No, 23/2014 on Regional Government. According to DKP, the authority of the local government fisheries service in Rawapening Lake is not yet clear. Apart from these problems, other priorities need to be considered by the institution. (Hidayati et al., 2018).

The use of grass carp in small amounts to reduce water hyacinth in Rawapening is very ineffective and inefficient. In addition, the grass carp fish released in Rawapening Lake are caught by fishermen. The inspiration for cleaning the Kerinci Lake which only used 2,000 grass carp for 10 years (Samuel et al., 2015) apparently could not be adopted in Rawapening Lake because of the cessation of the program before reaching the target of releasing 5,000,000 fish.

A new paradigm is needed in controlling the environmental degradation of Rawapening Lake by starting to calculate the growth rate of water hyacinth. The important thing that needs to be considered in the efforts to restore Rawapening Lake is to overcome the causes of the water hyacinth boom. Rawapening Lake management must be carried out holistically by reducing the entry of nutrients into water bodies. Rawapening Lake environmental conservation must be from



Figure 7. Mechanical harvesting of water hyacinth in Rawapening Lake

upstream to downstream. All of the water hyacinths should not be destroyed from Rawapening Lake, but their existence must be regulated and their growth rate controlled. The water hyacinth cover is maintained at a maximum of 15% of the lake area to maintain the sustainability of fish spawning and the people who use it for economic activities (RP Danau Rawapening, 2019). The existence of water hyacinth must be localized in the downstream area of the river which empties into Rawapening Lake. Water hyacinth is arranged as a belt that surrounds the estuary area by holding it using ropes and stakes so that it is not carried away due to wind gusts. Water hyacinth is used as bioremediation, because it can improve the quality of water around the plant cover (Wang et al., 2012). Water hyacinth also has the ability to reduce dissolved solids by 26%, phosphate by 33%, and hardness by 37% (Moyo et al., 2013).

In addition to controlling the growth rate of water hyacinth, the basic thing that must be immediately addressed to save Rawapening Lake is to organize the functions of these waters. Rawapening Lake, which has been an unorganized area, has made it a free-use area for the community (Nadjib, 2016). Rawapening Lake must be structured according to its function to make it easier for the Institution and the community who receive the benefits of the waters to maintain its sustainability. Several things that must be done immediately to conserve Rawapening Lake are: a. Zoning of the Rawapening Lake area according to its potential and uses (fisheries, agriculture, tourism, and culture); b. Determination of lake area boundaries; c. naturalization of watersheds; d. reforestation of water catchment areas.

CONCLUSIONS

The growth rate of water hyacinth must be considered as the basis for the successful management of the Rawapening Lake. The relative growth rate (RGR) of water hyacinth in Rawapening lakes ranges from 6.40–7.26%/day. In turn, the multiplication time (DT) of water hyacinth ranged from 9.6–10.8 day. Wet weight is also directly proportional to the number of clumps that fill the mesocosm area faster, and 1 m² will be full of water hyacinth within 21 days to 28 days.

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