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# Eutrophication State Monitoring for Unhealthy Aquatic Ecosystem via Free-Floating Macrophytes Pattern and Behavioral

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## ABSTRACT

Nutrient enrichment or eutrophication is a process of increasing plant nutrients in water bodies, frequently due to run-off from the land, which causes a dense growth of plant life. Eutrophication process is assisted by internal and external sources of nutrients such as nitrogen fixation and phosphate. In freshwater ecosystem, anthropogenic source of nutrients such as detergents, fertilizers and organic debris are among the sources of excess nutrients for nitrogen and phosphorus. It also has been proved to be a major factor which contributes to eutrophication and consequent algal blooms, spreading of certain aquatic macrophytes, depletion of oxygen and loss of key species leading to degradation of many freshwater ecosystems. This study aimed to discover the abilities of free-floating aquatic macrophyte species as an phytoindicator for eutrophication either at contamination or pollution level in polluted aquatic ecosystem to support their upcoming development and prospective through landscape ecology approach. The effects of nutrients (ammonium, phosphate, nitrate and nitrite), the free-floating aquatic macrophytes and locations have been studied on eutrophication in aquatic freshwater ecosystem. All species ( *Eichhorniacrassipes*, *Lemna minor*, *Neptuniaoleracea*, *Spirodellapolyrhiza*, *Salviniamolesta*and *Pistiastratiotes*) were detected with high level of phosphate at level III at all localities (Pahang, Selangor and Kelantan). Ammonium concentration was varied from class I to class III. In conclusion, changing in *E.crassipes*, *L.minor*and *S.polyrhiza* pattern and behavioral are proven to be the best phytoindicator for eutrophication state monitoring.

**Keywords:** eutrophication, phytoindicator, free-floating macrophytes, aquatic ecosystem.

## 1. Introduction

Malaysia is facing a daunting challengeby the contamination of aquatic ecosystem. This issue is a main ecological problem caused by rapid urbanization due to increasing of population, industrialization sectors and public attitudes among others (Al-Shami et al., 2010). As a result, this water contamination issue becomes a serious conflict as industrial and agriculture sector compete for water source, while upstream area compete with downstream area for the same reason (Ma et al., 2009). Eutrophication is a phenomenon that currently occurs in lakes all over the world including Malaysia. In recent report from Department of Environment, Malaysia (2011) stated that more than 60% lakes in Malaysia have facing the eutrophication phenomenon. This phenomenon occurs by addition of nutrients to water bodies including lakes, oceans, rivers and estuaries. The symptom of eutrophication effects are differ from every water bodies but commonly reported, macrophytes blooms are frequently occurred in some lakes and ponds (Zati and Salmah, 2008).

As reported by Sima et al. (2008), exceeding limit of nitrogen and phosphorus nutrients may become a threat to the ecosystem as in Malaysia, nutrients are major agriculture contaminants. One of the factors that contribute to this phenomenon is anthropogenic changes including catchment disturbance and nutrients which go into waterways through storm water and overland runoff and sewage works. Moreover, the contaminant sources are usually caused by agricultural runoff from fertilizer rich land such as crops and animal farm, plant nurseries and golf course.Water bodies with high concentration of biological oxygen demand (BOD), nutrients and pathogens may increase adverse effect to public health such as loss of water recreation potential, drinking and utilities water problem and decrease of seafood production (Shaw et al., 2003).

There are several terms used in eutrophication to indicate the level of stages in the process from clear water into algal blooms in the water bodies. Water bodies certainly will starts from oligotrophic which is nutritionally in poor status and overall primary productivity is low due to few development of either machrophyte or phytoplankton. On top of that, mesotrophic stage occurs when nutrients are added into the water bodies which caused phytoplankton biomass to increase. Final state of eutrophic arises when primary productivity and phytoplankton are highly increase while water quality is drop and consequently, development of nutrient is observed in both water and sediments (MohdLatiff et al., 2012).

Ecological indicator is a discrete expression or a part of the environment that provide quantitative information on ecological resources that reflecting the position of large system (Hunsker and Carpenter, 1990). They can be used to measure environmental conditions, to observe trends over time, to provide early signal of changes, and to detect and review the ecosystem patters (MohdLatiff, 2014). Aquatic plant or macrophyte has an expressive ability which they can produce carbon, mobilize phosphorus and transfer the trace elements in biochemical cycles and as bio concentration which may increase the nutrients and heavy metal accumulation (Shaharuddinet al., 2012). Furthermore, a studied by Milan et al. (2006), stated that some of macrophytes have capability to reduce or transform hazardous materials which present in aquatic environment. Therefore, the ability of macrophyte species can lead this species to be one of the significantecological indicators particularly for contaminated aquatic ecosystem.

## 2. Materials and Methods

10 water samples were collected in triplicate in plastic containers at 15 selected siteslocated at Selangor, Pahang and Kelantan using standard methods of collection. Water samples then were stored at 4ºC and the addition of 2.5ml chloroform in 500 ml of water were done for preservation of samples and further analysis. All water samples were analyzed by using HACH DR 3800 Spectrophotometer for different nutrients detection, which are nitrite ($NO_2$), nitrate ($NO_3$) ammonium ($NH_4$), and phosphate ($PO_4$).

All representative values were displayed by standard deviation and mean value. Statistical analyses were performed and analysis of variance (ANOVA) was calculated to test significance of the variation in the data and the validity of the data, between the floating aquatic plant species, different nutrients and localities.

## 3. Results and Discussion

Six different free-floating aquatic plant species collected from total of 15 sites in Selangor, Pahang and Kelantan which are *E.crassipes, L.minor, N.oleracea, P.stratiotes, S.polyrhiza,* and*S.molesta*were analysed for nitrite, nitrate, ammonium and phosphate total content; Dissolved Oxygen (DO) and pHfrom three different locations which are Selangor, Pahang and Kelantan. Analysis of variance on each of three locations data confirmed the previous findings by exhibiting highly significant differences ($P< 0.0001$) between the free-floating aquatic plant species widespread and the nutrients (nitrite, nitrate, ammonium and phosphate) content. When the data is combined from all three locations, further analysis of variance also established highly significant differences ($P< 0.0001$) between the six species of free-floating aquatic plant, the nutrients (nitrite, nitrate, ammonium and phosphate) content, the locations and all combinations of interactions. This clearly demonstrates that freshwater environment with abundance of invasive macrophyte species can have asignificantimpact and indication on the sequestration of nutrients content. The significance of the interaction components highlight that the changes in nutrients composition are complex and the reactions are not consistent through all free-floating aquatic plant species. Investigation of the summarised data shown that, from the 6 free-floating macrophytes species analysed at all three different locations, all shows as prospective ecological indicator for unhealthy aquatic ecosystems or as phytoindicator for eutrophication either at high or low level contamination. All species were detected with high level of phosphate at class III which is polluted. Phosphate concentration range from 0.29 ± 0.09 mg/l to 5.65 ± 0.20 mg/l detected at all localities (Selangor, Pahang and Kelantan). Ammonium concentration was various from class I to class III. Regardless of nitrate level, although detected at all sites, but did not hit any contamination or pollution level. Nitrite was not detected or absent at all sites due to preference of ammonium nutrient for aquatic plant, in addition nitrite was only a by-product from nitrification process.In study of certain location in Kelantan, low level of nitrate and ammonium were observed whereas in Pahang and Selangor ammonium was detected mostly in high level. This might be due to amount of clay particles or organic matter in the soil which contribute different type of N inorganic forms. Previous studies reported that nutrients in the sediment can positively affect growth rates (Mony et al., 2007). The result in Kelantan shows that water hyacinths (*Eichhorniacrassipes*) are the most commonly perform as the highest potential for water pollution controlas it known to accumulate nutrients (Cornwell et al., 1977) and potentially toxic water pollutants (Wolverton and Mc Donald, 1975).

**Table-1.**Mean (±se, *n* = 24) value (mg/l) of nutrients content (nitrite, nitrate, ammonium and phosphate), D.O and pH in water samples dominated by *E.crassipes, S.polyrhiza, N.oleracea* and *L.minor* at 5 selected site in Selangor with analysis of variance (ANOVA).

| SPECIES | NITRITE (mg/l) | NITRATE (mg/l) | AMMONIUM (mg/l) | PHOSPHATE (mg/l) | D.O (mg/l) | pH | LEVEL OF NUTRIENT CONTENT |
|---|---|---|---|---|---|---|---|
| 1.*N.oleracea/L.minor* | ND | 1.50 ±0.31 | 0.38±0.02 (Class IIB) | 4.83±0.92 (Class III) | 0.32 ±0.04 (Class V) | 6.88±0.02 (Class IIB) | LOW – $NO_3$ HIGH – $PO_4$, $NH_4$ |
| 2. *L.minor* | ND | 1.03 ±0.17 | 0.90±0.11 (Class III) | 5.65±0.20 (Class III) | 0.34±0.04 (Class V) | 6.87±0.02 (Class IIB) | LOW – $NO_3$ HIGH – $PO_4$, $NH_4$ |
| 3. *N.oleracea* | ND | 0.07 ±0.08 | ND | 1.86±0.31 (Class III) | 0.44±0.02 (Class V) | 6.79±0.02 (Class IIB) | LOW – $NO_3$ HIGH – $PO_4$ |
| 4. *S.polyrhiza* | ND | 2.54 ±1.20 | 1.14±0.17 (Class III) | 1.33±0.49 (Class III) | 0.22±0.04 (Class V) | 6.26±0.33 (Class IIB) | LOW – $NO_3$ HIGH – $PO_4$, $NH_4$ |
| 5.*E.crassipes* | ND | 1.78 ±0.61 | 1.14±0.15 (Class III) | 3.46±0.25 (Class III) | 0.81±0.08 (Class V) | 6.61±0.07 (Class IIB) | LOW – $NO_3$ HIGH –$PO_4$, $NH_4$ |
| ANOVA | **** | **** | **** | **** | | | |

ND: not detected. ****Highly significant at P < 0.0001

**Table-2.** Mean (±SE, *n* = 24) value (mg/l) of nutrients content (nitrite, nitrate, ammonium and phosphate), D.O and pH in water samples dominated by *E.crassipes, L.minor, S.molesta,* and *N.oleracea* at selected sites in Pahang with analysis of variance (ANOVA).

| SPECIES | NITRITE (mg/l) | NITRATE (mg/l) | AMMONIUM (mg/l) | PHOSPHATE (mg/l) | D.O (mg/l) | pH | LEVEL OF NUTRIENT CONTENT |
|---|---|---|---|---|---|---|---|
| 1.*E.crassipes* | ND | 0.46 ±0.15 | 0.30±0.10 (Class IIB) | 1.31±0.25 (Class III) | 0.18±0.08 (Class V) | 6.32±0.01 (Class IIB) | LOW – $NO_3$ HIGH – $PO_4$, $NH_4$ |
| 2. *L.minor* | ND | 0.90±0.51 | 1.36±0.08 (Class III) | 1.87±0.36 (Class III) | 0.44±0.06 (Class V) | 6.08±0.39 (Class IIB) | LOW – $NO_3$ HIGH - $PO_4$, $NH_4$ |
| 3. *S.molesta* | ND | 0.58±0.31 | ND | 0.79±0.31 (Class III) | 0.89±0.61 (Class V) | 5.77±0.29 (Class III) | LOW – $NO_3$ HIGH – $PO_4$ |
| 4. *N.oleracea* | ND | 0.06±0.10 | 0.44±0.08 (Class IIB) | 0.29±0.09 (Class III) | 1.2±0.05 (Class IV) | 6.21±0.02 (Class IIB) | LOW – $NO_3$ HIGH - $PO_4$, $NH_4$ |
| 5. *E.crassipes / N.oleracea* | ND | 0.51±0.24 | 0.91±0.02 (Class III) | 0.84±0.24 (Class III) | 0.26±0.14 (Class V) | 5.37±2.17 (Class III) | LOW – $NO_3$ HIGH – $PO_4$, $NH_4$ |
| ANOVA | **** | **** | **** | **** | | | |

ND: not detected. ****Highly significant at P < 0.0001

**Table-3.** Mean (±SE, *n* = 24) value (mg/l) of nutrients content (nitrite, nitrate, ammonium and phosphate), D.O and pH in water samples dominated by *S.molesta*, *P.stratiotes* and *E.crassipes* at selected sites in Kelantan with analysis of variance (ANOVA).

| SPECIES | NITRITE (mg/l) | NITRATE (mg/l) | AMMONIUM (mg/l) | PHOSPHATE (mg/l) | D.O (mg/l) | pH | LEVEL OF NUTRIENT CONTENT |
|---|---|---|---|---|---|---|---|
| 1.*S.molesta*& *E.crassipes* | ND | 0.58 ±0.20 | 0.05±0.02 | 1.20±0.38 (Class III) | 0.21±0.07 (Class V) | 5.97±0.04 (Class III) | LOW - $NH_4$, $NO_3$ HIGH - $PO_4$ |
| 2. *P.stratiotes* | ND | 0.37±0.17 | 0.12±0.17 (Class I) | 1.38±0.80 (Class III) | 1.23±0.76 (ClassIV) | 6.41±0.19 (Class IIB) | LOW - $NH_4$, $NO_3$ HIGH - $PO_4$ |
| 3. *E.crassipes* | ND | 0.46±0.32 | 0.17±0.04 (Class I) | 1.31±0.71 (Class III) | 0.41±0.11 (Class V) | 6.11±0.04 (Class IIB) | LOW - $NH_4$, $NO_3$ HIGH - $PO_4$ |
| 4. *E.crassipes* | ND | 0.45±0.07 | 0.54±0.24 (Class IIB) | 0.80±0.22 (Class III) | 1.96±1.67 (Class IV) | 6.22±0.24 (Class IIB) | LOW -$NO_3$ HIGH - $PO_4$, $NH_4$ |
| 5. *S.molesta* | ND | 1.25±0.34 | 0.10±0.07 (Class I) | 0.75±0.19 (Class III) | 3.31±0.13 (Class III) | 6.29±0.07 (ClassIIB) | LOW - $NH_4$, $NO_3$ HIGH - $PO_4$ |
| ANOVA | **** | **** | **** | **** | | | |

ND: not detected. ****Highly significant at $P < 0.0001$

**Figure-1.** Free Floating Macrophytes, *S.molesta*, *P.stratiotes*, *E.crassipes*, *L.minor*, *N.oleracea*, and *S.polyrhiza* (left to right) used for indicating eutrophication in Unhealthy Aquatic Ecosystem.

# 4. Conclusion

Nutrient availability can influence the abundances of plant community structure in natural aquatic. Therefore *E.crassipes*, *L.minor*, *S.molesta* and *N.oleracea* were the most common and dominant species observed in all three locations in this study which proven can tolerate and coping either low or high level of eutrophication. Moreover, the effects of nutrients (phosphate, ammonium, nitrate and nitrite); the free-floating macrophytes and locations have been studied on eutrophication level monitoring in aquatic freshwater bodies ecosystem. All species (*L.minor*, *E.crassipes*, *S.polyrhiza*, *N.oleracea*, *S.molesta* and *P.stratiotes*) were detected with high level of phosphate at class III which is polluted. In conclusion, the most reliable phytoindicator for overall experiment were *L.minor*, *E.crassipes* and *S.polyrhiza.* In addition, every floater aquatic plant species that has been tested was confirmed as reliable phytoindicator agent to detect eutrophication in unhealthy aquatic ecosystem.

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