Water quality parameters contributing to the invasion of water hyacinth (*Eichhornia crassipes*) in the Anawilundawa reservoir in Sri Lanka

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**Abstract** *Eichhornia crassipes* has been found to invade the Anawilundawa reservoir located within Ramsar wetland in the northwestern region of Sri Lanka. Present study was carried out to determine the water quality parameters that could contribute to its invasion and identify an effective control measure. During the study period of March-November 2017, mean values for Secchi depth, water depth and nitrate content in areas where *E. crassipes* was present (7.9 cm, 12.4 cm and 475 µg L⁻¹ respectively) were found to be significantly lower (p<0.05) than in areas where it was absent (9.0 cm, 14.0 cm and 726 µg L⁻¹ respectively). In areas where *E. crassipes* was present, low nitrate content may be due to its absorption and low Secchi depth may be due to trapping of detritus. Principal Component Analysis showed that during the monsoon period, high pH combined with low levels of conductivity, salinity, total dissolved solids and total phosphorus contributed for its invasion. From March to July, coverage of *E. crassipes* gradually decreased and in August the reservoir was completely dry and *E. crassipes* was present only as sparsely distributed individual plants rooted to the exposed reservoir bed. In September, with incoming water of inter-monsoonal rains and surface runoff, these plants got uprooted and started floating and by October they were flowering. In June, *E. crassipes* was confined to an area of about 0.5 ha with a mean depth of 13.3 cm. During this month it can be easily removed manually with a little amount of human labour which can be obtained from the riparian community who use this reservoir for irrigation and domestic purposes. However, if it is to be removed, a suitable indigenous plant species that interact with aquatic avifauna has to be introduced to ensure the continuity of some environmental services provided by this reservoir.

**Keywords:** Invasive alien species, *Eichhornia crassipes*, physicochemical parameters, Ramsar wetland

**INTRODUCTION**

Anawilundawa reservoir is one of the seven cascading reservoirs in the Anawilundawa Ramsar wetland in the north western region in Sri Lanka (IUCN and CEA 2006). It has been constructed in 1140 AD to store water for irrigation (Perera et al. 2005). As numerous other man-made reservoirs in Sri Lanka, the Anawilundawa reservoir also contributes significantly to high biodiversity (Jayasinghe 2000). However, a majority of ancient reservoirs in Sri Lanka are facing many environmental challenges today due to several reasons including the spread of invasive alien species (IUCN and CEA 2006). *Eichhornia crassipes* (Water hyacinth), one of the worst aquatic weeds in the world has been recorded in many of these reservoirs including the Anawilundawa reservoir (Gunasekara 2011), which is located in the migratory route of birds that enter Sri Lanka through the north western and northern coasts (Angammana 2005). *E. crassipes* was reported to degrade water quality, accelerate the loss of habitats for fish and wildlife, and alter the ecological balance contributing to loss of biodiversity (Gunaratne et al. 2009).

Dense mats of *E. crassipes* reduce photosynthesis of phytoplankton affecting the primary production of the aquatic ecosystems and also restrict the dissolving of atmospheric oxygen through air-water interface. These, together with microbial breakdown of decaying plant material may result in the depletion of dissolved oxygen content in waterbodies leading to fish kills (Yongo et al. 2017).
E. crassipes is sensitive to high salinities and grows only in fresh and slightly brackish waters. It normally floats and when waterbodies dry up, it attaches to the exposed reservoir bed and survives. It can tolerate wide ranges of nutrient levels, acidity and alkalinity. These features enable it to colonize and survive in many aquatic habitats (Parsons and Cuthbertson 2001, Elenwo and Akankali 2016).

No detail studies have so far been carried out on the invasion of E. crassipes in the Anawilundawa reservoir (Figure 1). Present study was carried out with the objectives of determining the water quality parameters that significantly affect the invasion of E. crassipes in this reservoir and identifying a suitable method for its control.

**Fig 1 Map of the Anawilundawa Reservoir**

**MATERIALS AND METHODS**

Monthly sampling was carried out in the Anawilundawa reservoir from March to November 2017 at six sampling sites selected at random. Of these, E. crassipes was present only in three sites. These were not permanent sites because some of them got exposed during the study period due to receding water level of the reservoir and therefore new sites had to be selected during the course of the study.

On each sampling occasion, conductivity, pH, salinity, surface water temperature and Total Dissolved Solids (TDS) were measured at the site itself in triplicate using a pre-calibrated multimeter (HACH: HQ40d multi). The depth of the water column was measured using a calibrated pole and Secchi depth was measured using a Secchi disc. Water samples were collected in triplicate from each sampling site and fixed in the field as described by APHA (1999) and transported to laboratory to determine nitrate, total phosphorus and Chlorophyll-a contents. Nitrate content was determined using ultraviolet spectrophotometric screening method, total phosphorus concentration was measured using the persulfate digestion method followed by ascorbic acid method and Chlorophyll-a content was determined using the standard procedure as described by APHA (1999).

Data were tested for normality using the Anderson Darling test and normally distributed data were analyzed using the student t test and two way ANOVA followed by Tukey-Kramer test. When the data were not distributed normally Mann Whitney U test and Kruskal-Wallis test followed by Nemenyi test were used. Principal component analysis was done using the data for the monsoonal (May-September) and inter-monsoonal (March-April and October-November) periods. For PCA, log transformed data were used. MINITAB software (version14) was used for the statistical analysis.

**RESULTS**

In March 2017, most of the reservoir surface was covered with E. crassipes. In some places, thick mats of E. crassipes were present. Purple swamp hen (Porphyrio porphyrio) was observed to breed in these areas in March. From March to June the coverage of E. crassipes decreased and in June it was confined to a very small area of about 0.5 ha. The mean depth of water during this month was 13 cm with a maximum depth of 30 cm. In July, it was not present although there was a little amount of water in the reservoir. In the exposed areas, few isolated plants of E. crassipes were observed to be rooted in the dry reservoir bed. In August, the reservoir was completely dry and in September, with inter-monsoonal rains and surface runoff, it started filling up and E. crassipes plants that were rooted in the reservoir bed got detached from the soil and started floating. Their growth increased rapidly and fully grown flowering plants were observed in November.
Mean ± Standard Error of Mean (SEM) values for different water quality parameters at sites where *E. crassipes* was present and absent are given in Table 1. Mean values for Secchi depth, water depth and nitrate content in sites where *E. crassipes* was present were significantly lower (p<0.05) than in sites where it was absent.

During the study period, the lowest pH and the highest conductivity, TDS, salinity and total phosphorus were recorded in July just before drying up of the reservoir. The highest pH and the lowest water temperature, conductivity, TDS and salinity values were recorded in November when the water level was gradually increasing with incoming surface runoff and heavy inter-monsoonal rains (Tables 2 and 3). The lowest depth was recorded in September when the reservoir was started filling up while the highest depth and water temperature, and lowest total phosphorus level were recorded in April (Table 2).

Highest nitrate and Chlorophyll-a contents were recorded in March during the inter-monsoon period (Table 2). Nevertheless, mean values for conductivity, TDS, salinity, Secchi depth, water depth, Chlorophyll-a and nitrate content did not show a significant temporal variation (p>0.05) (Tables 2 and 3).

In areas where *E. crassipes* was present (Table 2), mean pH values in September and October were significantly lower than those of November while the mean values for water temperature in March, April and October were significantly higher than those of May, September and November (p<0.05). Mean value for total phosphorus content was significantly higher in November than in all other months (p<0.05) (Table 2).

In the areas where *E. crassipes* was absent, pH was significantly higher in November, total phosphorus level was significantly higher in July and water depth was significantly higher in March and April than in other months (p<0.05). Water temperature in March and April was significantly higher than in May, September and November (p<0.05) (Table 3).

Results of the PCA are given in Table 4 and Figure 2. The first two principal components explained 94% of the total variability. During the monsoonal period, the sites where *E. crassipes* was present were separated from the sites where it was absent. During this period, high pH coupled with low values for conductivity, salinity, TDS and total phosphorus content contributed to the presence of *E. crassipes* in some regions of the reservoir.

### Table 1 Mean ± Standard Error of Mean of different water quality parameters at sites where *E. crassipes* was present and where it was absent

| Parameter          | *E. crassipes* Present | *E. crassipes* Absent |
|--------------------|------------------------|-----------------------|
| pH                 | 7.12 ± 0.08<sup>a</sup> | 7.05 ± 0.11<sup>a</sup> |
| Temperature (°C)   | 32.50 ± 0.28<sup>a</sup> | 33.00 ± 0.34<sup>a</sup> |
| Conductivity (μS/cm) | 2714.90 ± 203.00<sup>a</sup> | 3580.70 ± 360.00<sup>a</sup> |
| TDS (mg/L)         | 1437.80 ± 110.00<sup>a</sup> | 1884.00 ± 201.00<sup>a</sup> |
| Salinity (%)       | 1.45 ± 0.11<sup>a</sup> | 1.95 ± 0.21<sup>a</sup> |
| Secchi depth (cm)  | 7.9 ± 0.7<sup>a</sup> | 9.0 ± 0.6<sup>b</sup> |
| Water depth (cm)   | 12.4 ± 1.0<sup>a</sup> | 14.0 ± 0.8<sup>b</sup> |
| Nitrate concentration (mg/L) | 0.475 ± 0.053<sup>a</sup> | 0.726 ± 0.082<sup>b</sup> |
| Total phosphorus concentration (mg/L) | 0.370 ± 0.041<sup>a</sup> | 0.598 ± 0.095<sup>a</sup> |
| Chlorophyll-a (mg/m²) | 11.13 ± 1.51<sup>a</sup> | 10.31 ± 1.19<sup>a</sup> |

Different superscript letters in each row denote significant differences (p<0.05).
Table 2 Monthly mean ± standard error of mean (SEM) values for different water quality parameters at sites where *E. crassipes* was present in the Anawilundawa Reservoir. (Temp = Temperature, Cond = Conductivity, TDS = Total dissolved solids, SD = Secchi depth, WD = Water depth, NC = Nitrate concentration, TP = Total phosphorus concentration, Chl-a = Chlorophyll-a content). The same superscript letter in each row denotes that there is no significant difference (p > 0.05).

| Parameter | March       | April       | May         | June        | September   | October     | November    |
|-----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| pH        | 7.09 ± 0.21ab | 7.23 ± 0.76ab | 7.24 ± 0.52ab | 7.35 ± 0.17ab | 6.70 ± 0.12b | 6.60 ± 0.18b | 7.62 ± 0.33a |
| Temp (°C) | 33.90 ± 0.61a | 34.1 ± 0.17a  | 31.2 ± 0.26bc | 33.00 ± 0.69ab | 30.4 ± 0.62c | 34.50 ± 0.23a | 30.3 ± 0.63c |
| Cond (μS/cm) | 2081.9 ± 53.6a | 3330.0 ± 396.0a | 3280.0 ± 42.2a | 5383.3 ± 136.0a | 2214.0 ± 314.0a | 2305.7 ± 446.0a | 409.8 ± 81.8a |
| TDS (mg/L) | 1051.2 ± 28.0a | 1718.9 ± 214.0a | 1688.6 ± 23.1a | 2826.7 ± 67.2a | 1402.0 ± 271.0a | 1177.9 ± 233.0a | 199.7 ± 41.3a |
| Salinity (ppt) | 1.06 ± 0.03a | 1.74 ± 0.22a | 1.71 ± 0.03a | 2.88 ± 0.06a | 1.38 ± 0.27a | 1.19 ± 0.24a | 0.19 ± 0.04a |
| SD (cm)    | 19.0 ± 1.0a  | 5.8 ± 0.7a   | 3.2 ± 0.5a   | 7.0 ± 0.6a   | 6.0 ± 1.0a  | 5.3 ± 0.2a  | 9.0 ± 2.5a  |
| WD (cm)    | 19.0 ± 1.0b  | 22.8 ± 3.7b  | 7.7 ± 1.2a   | 13.3 ± 0.8a  | 6.0 ± 1.0a  | 7.0 ± 0.3a  | 10.7 ± 2.3a |
| NC (mg/L)  | 0.366 ± 0.078a | 0.579 ± 0.153a | 0.155 ± 0.032a | 0.459 ± 0.080a | 0.201 ± 0.069a | 0.88 ± 0.211a | 0.675 ± 0.130a |
| TP (mg/L)  | 0.276 ± 0.052abc | 0.187 ± 0.016bc | 0.433 ± 0.017abc | 0.399 ± 0.035abc | 0.588 ± 0.239ab | 0.436 ± 0.060abc | 0.641 ± 0.120a |
| Chl-a (mg/m³) | 19.21 ± 6.25a | 11.48 ± 5.49a | 6.70 ± 2.01a | 6.73 ± 1.71a | 4.48 ± 0.95a | 15.09 ± 2.37a | 14.19 ± 4.35a |

* *E. crassipes* was not present in July.
Table 3 Monthly mean ± Standard Error of Mean (SEM) values for different water quality parameters at sites where *E. crassipes* was absent in the Anawilundawa Reservoir. (Abbreviations for physicochemical parameters are same as for Table 2). The same superscript letter in each row denotes that there is no significant difference (p > 0.05).

| Parameter   | March          | April         | May           | June          | July          | September     | October       | November      |
|-------------|----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| pH          | 7.21 ± 0.16<sup>b</sup> | 7.36 ± 0.08<sup>b</sup> | 7.24 ± 0.06<sup>b</sup> | 6.76 ± 0.12<sup>bc</sup> | 5.99 ± 0.31<sup>bc</sup> | 6.88 ± 0.15<sup>bc</sup> | 6.55 ± 0.13<sup>bc</sup> | 8.44 ± 0.45<sup>a</sup> |
| Temp (°C)   | 35.5 ± 0.31<sup>ab</sup> | 36.7 ± 0.11<sup>a</sup> | 31.4 ± 0.10<sup>cd</sup> | 31.1 ± 0.48<sup>cd</sup> | 33.7 ± 0.11<sup>bc</sup> | 31.1 ±0.59<sup>cd</sup> | 34.3 ± 0.84<sup>ab</sup> | 29.7 ± 0.44<sup>d</sup> |
| Cond (μS/cm)| 2360.7± 168.0<sup>a</sup> | 3842.2±546.0<sup>a</sup> | 3248.9±28.4<sup>a</sup> | 4787.8 ± 17.4<sup>a</sup> | 10225.6±841.0<sup>a</sup> | 2252.4 ± 327.0<sup>a</sup> | 1392.8 ± 440.0<sup>a</sup> | 535.1 ± 55.1<sup>a</sup> |
| TDS (mg/L)  | 1143.7 ± 43.1<sup>a</sup> | 1984.6±295.0<sup>a</sup> | 1668.7±15.4<sup>a</sup> | 2486.7 ± 37.3<sup>a</sup> | 5591.1 ± 490.0<sup>a</sup> | 1435.2 ± 289.0<sup>a</sup> | 502.0 ± 129.0<sup>a</sup> | 260.2 ± 29.7<sup>a</sup> |
| Salinity (ppt) | 1.16 ± 0.05<sup>a</sup> | 2.02 ± 0.30<sup>a</sup> | 1.69 ±0.02<sup>a</sup> | 2.54 ± 0.00<sup>a</sup> | 5.78 ± 0.51<sup>a</sup> | 1.46 ± 0.30<sup>a</sup> | 0.70 ± 0.23<sup>a</sup> | 0.26 ± 0.03<sup>a</sup> |
| SD (cm)     | 14.1 ± 2.0<sup>a</sup> | 10.0 ± 1.8<sup>a</sup> | 6.0 ± 0.8<sup>a</sup> | 8.7 ± 0.7<sup>a</sup> | 7.7 ± 0.7<sup>a</sup> | 8.8 ± 2.8<sup>a</sup> | 8.0 ± 1.3<sup>a</sup> | 8.7 ± 1.3<sup>a</sup> |
| WD (cm)     | 21.0 ± 3.0<sup>b</sup> | 20.5 ± 2.4<sup>b</sup> | 10.7 ± 0.3<sup>a</sup> | 13.0 ± 0.5<sup>a</sup> | 10.7 ± 0.3<sup>a</sup> | 11.3 ± 2.3<sup>a</sup> | 13.7 ± 0.3<sup>a</sup> | 11.0 ± 2.4<sup>a</sup> |
| NC (mg/L)   | 1.186 ± 0.401<sup>a</sup> | 0.579 ± 0.089<sup>a</sup> | 0.199±0.064<sup>a</sup> | 0.456 ± 0.026<sup>a</sup> | 0.723 ± 0.125<sup>a</sup> | 0.605 ± 0.136<sup>a</sup> | 0.986 ± 0.094<sup>a</sup> | 1.070 ± 0.397<sup>a</sup> |
| TP (mg/L)   | 0.254 ± 0.015<sup>b</sup> | 0.342 ± 0.033<sup>b</sup> | 0.373±0.025<sup>b</sup> | 0.492 ± 0.021<sup>b</sup> | 1.786 ± 0.598<sup>a</sup> | 0.617 ± 0.203<sup>b</sup> | 0.277 ± 0.036<sup>b</sup> | 0.628 ± 0.133<sup>b</sup> |
| Chl-a (mg/m<sup>3</sup>) | 5.84 ± 1.37<sup>a</sup> | 4.95 ± 0.72<sup>a</sup> | 4.49 ± 1.06<sup>a</sup> | 7.00 ± 1.83<sup>a</sup> | 15.27 ± 3.60<sup>a</sup> | 13.77 ± 3 91<sup>a</sup> | 17.24 ± 6.38<sup>a</sup> | 14.19 ± 0.86<sup>a</sup> |
Table 4 Summary of the results of principal component analysis for water quality parameters

|                     | PC1     | PC2     |
|---------------------|---------|---------|
| Eigen value         | 7.598   | 1.800   |
| % Variation         | 76.0    | 18.0    |
| Cumulative % variation | 76.0   | 94.0    |
| Eigen vectors       |         |         |
| pH                  | 0.305   | 0.363   |
| Temperature         | 0.348   | -0.137  |
| Conductivity        | -0.343  | -0.219  |
| TDS                 | -0.347  | -0.202  |
| Salinity            | -0.344  | -0.215  |
| Secchi depth        | 0.303   | -0.409  |
| Water depth         | 0.331   | -0.293  |
| Nitrate             | 0.303   | -0.292  |
| Phosphate           | -0.292  | -0.432  |
| Chlorophyll-a       | 0.226   | -0.435  |

DISCUSSION

Invasive species are considered to be a leading threat to biodiversity throughout the world (Mack et al. 2000). Although *E. crassipes* is an aquatic plant, when Anawilundawa reservoir was completely devoid of water during the dry season, this species can attach to the reservoir bed and survive. Hence, seasonal drying of reservoirs does not help to control its invasion. Similar observations have been made by Parson and Cuthbertson (2001) in Australian waters.

Kasselmann (1995) reported that *E. crassipes* grows at temperatures ranging from 12°C to 35°C. Water temperature in the Anawilundawa reservoir was within this range throughout the study period. Extensive mat formation was seen in November with the rising water level with inter-monsoonal rains and the mean water temperature during this month was 30.3°C at the sites where *E. crassipes* was present and 29.7°C at the sites where it was absent (Tables 2 and 3). Slightly higher temperature at sites where it was present may be due to interference with the exchange of heat between the water surface and the atmosphere as suggested by Navarro and Phiri (2000).

Nitrate concentrations in 20 reservoirs in the North western Province of Sri Lanka where Anawilundawa reservoir is located have been reported to be in the range of 1.1 - 5.6 mg/L (Sangakkara and Wijeyaratne 2015), which are very much higher than the values recorded in the present study. Those reservoirs are located in intensive agricultural areas where excessive usage of fertilizer is common and surface runoff had brought in large amounts of nutrients into those reservoirs. Therefore, although the abundance of birds, especially that of migratory species is high in the Anawilundawa reservoir, it appears that their droppings have not contributed to increase the nitrate concentration to a level recorded in the reservoirs located in the areas of intensive agriculture. Nevertheless, the nitrate and total phosphorus levels recorded in the present study were higher than those recorded in Diyawanna Lake (0.01-0.04 mg/L), which is an urban wetland in Sri Lanka (Wijeyaratne and Bellanthudawa 2017). During the period of low rainfall, a large number of cattle use the exposed reservoir bed for grazing and cow dung which is added during this period would have contributed to high nutrient levels in this water body. Another reason may be the higher abundance of birds, especially that of the migratory species in the Anawilundawa reservoir than in Diyawanna Lake. Gunaratne et al. (2015) reported that nutrient levels including nitrates and phosphates...
are very high in the areas where Asian openbill (Anastomus oscitans) breeds in the Anawilundawa reservoir due to accumulation of their droppings. Total phosphorus levels recorded in the Anawilundawa reservoir during the present study are higher than those recorded for the Madu Ganga estuary (Silva and Wijeyaratne 2017), which is another Ramsar wetland rich in avifauna. The reasons for this may be the absence of nutrient input by cattle as well as the lotic nature of this estuary.

Significantly lower (p < 0.05) nitrate levels in the areas where E. crassipes was present than in areas where it was absent may possibly be due to absorption by these plants as reported by Gunaratne (2013). However, there was no significant difference in the mean values of the total phosphorus levels between the areas where E. crassipes was present and where it was absent (p=0.05). This indicates selective absorption of nutrients by E. crassipes as reported by Ultsch and Anthony (1973). Ogunlade (1996) also reported that E. crassipes has the ability to remove nutrients and heavy metals from aquatic environments. Therefore, the present study also indicates that E. crassipes has the potential to significantly reduce nutrient concentrations in the Anawilundawa reservoir. Similar observations have been made by Pinto-Coelho and Greco (1999) in the Pampulha reservoir in Brazil.

Total phosphorus level is one of the parameters used to determine the trophic status of water bodies. According to the standards stipulated by USEPA (2000), total phosphorus levels in oligotrophic, mesotrophic and eutrophic water bodies are < 0.012, 0.012-0.024 and >0.024 mg/L respectively. In the present study, total phosphorus concentration in the Anawilundawa reservoir was found to vary from 0.187 mg/L to 1.786 mg/L. Therefore, according to USEPA (2000) standards this reservoir can be classified as eutrophic.

Migratory birds were not observed in the reservoir during May. This may possibly have contributed for the low nitrate concentration in the reservoir during this month as droppings were only from the native avifauna.

Nutrients in seasonal reservoirs get concentrated with receding water levels due to the low rainfall and high evaporation rate. This may be the reason for the high level of total phosphorus recorded in July. Similar observations have been reported by Wijesundara et al. (2012) in several seasonal reservoirs in Sri Lanka. Absence of E. crassipes in this month may have further contributed for this.

There is a significant difference in the water depth between the areas where E. crassipes was present (12.4 ± 1.0 cm) and where it was absent (14.0 ± 0.8 cm). This may be due to drifting of E. crassipes to areas closer to the edges of the reservoir by wind. Such drifting is possible because E. crassipes plant has considerable buoyancy due to parenchyma. Further, its leaves act as sails in windy conditions (Hasan and Rina, 2009). Similar wind driven distribution of E. crassipes has also been reported in Lake Victoria (Makhanu1997).

During the present study, it was found that the areas where E. crassipes was present had a significantly lower Secchi depth than in areas where it was absent (p<0.05). Similar observations have been made by Uka and Chukwuka (2007) in the Awba reservoir, Nigeria. Villamagna (2009) showed that E. crassipes trap detritus and phytoplankton, which results in a decrease in water clarity when compared to open water. However, mean values for Chlorophyll-a content in the areas where E. crassipes was present and where it was absent were not significantly different from each other (p>0.05). Therefore, the main reason for the significant decrease in Secchi depth at the sites where E. crassipes was present may be trapping of detritus by this species.

PCA indicated that during inter-monsoon periods, the areas where E. crassipes was present and where it was absent could not be separated based on water quality parameters. During the monsoon period, however, high pH and low levels of conductivity, salinity, TDS and total phosphorus content contributed for the separation of the areas where E. crassipes was present from areas where it was absent (Table 4 and Figure 2). Therefore, it appears that high pH and low levels of conductivity, salinity, TDS and total phosphorus content were collectively contributed for the invasion of E. crassipes in this reservoir during the monsoon period.

Mack et al. (2000) reported that E. crassipes cannot be eradicated completely from a water body. Nevertheless, their invasion can be controlled and the control method should be identified based on multitude of factors including the size and spatial configuration of the area to be controlled (Thayer and Ramey 1986), seasonal weather patterns, designated uses of the water body (Gibbons et al. 1994) and available financial and human resources.
Seeds of *E. crassipes* germinate in warm, shallow water or on moist sediments and flowering may occur 10-15 weeks thereafter. Plants may flower throughout the year if the climate and environmental conditions are favourable (Jones 2008, Terblanche et al. 2014). During the present study, it was observed that the flowering of *E. crassipes* begins in November. Controlling it before flowering would be more successful. In June, *E. crassipes* was present only in a very small area of about 0.5 ha of the reservoir. Mean depth of this area was only 13.3 cm and the maximum depth was only 30.0 cm. During this month it can be removed very easily with a very little amount of manual labour, which can be obtained from the riparian community who uses this reservoir for agriculture and domestic purposes. However, there is a close interaction between *E. crassipes* plants and aquatic avifauna. Gunaratne et al. (2015) reported that Asian openbill (*Anastomus oscitans*) breeds in the areas of this reservoir where a thick mat of aquatic plants consisting of several species including *E. crassipes* is present. During the present study too, it was observed that purple swamp hen (*Porphyrio porphyrio*) breeds in the areas with dense *E. crassipes* mats. Therefore, if *E. crassipes* is to be removed, as Gunaratne et al. (2015) have suggested it is necessary to introduce a suitable indigenous aquatic plant species that can provide similar environmental service to aquatic avifauna.

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