

## Effects of Water hyacinth (*Eichhornia crassipes Solm*) Infestation on water quality, fish species diversity and abundance in the Nyanza Gulf of Lake Victoria, Kenya

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### Abstract

This study compared water quality parameters, fish species diversity and abundance in the water hyacinth infested and non-infested areas. The mean ( $\pm$ SD) water temperature of the infested and non-infested areas were  $25.60\pm 4.39^{\circ}\text{C}$  and  $24.62\pm 4.94^{\circ}\text{C}$  respectively. Dissolved oxygen  $2.44\pm 1.14\text{ mg l}^{-1}$  of the infested area was significantly lower than non-infested ( $4.24\pm 0.96\text{ mg l}^{-1}$ ) ( $p<0.05$ ). The mean pH of infested and non-infested areas were  $6.05\pm 1.04$  and  $7.62\pm 0.42$  respectively. The lowest ( $6.97\pm 0.183\text{ mg l}^{-1}$ ) nitrate was recorded in infested and the highest ( $11.34\pm 1.46\text{ mg l}^{-1}$ ) in non-infested areas. Infested areas had high fish species diversity (2.00) and evenness (0.93). In the infested areas, *Protopterus aethiopicus* (35%) had the highest relative abundance, followed by *Clarias gariepinus* (28%), while in the non-infested areas, *Lates niloticus* had the highest abundance (23%) followed by *Oreochromis niloticus* (18%). The abundance of haplochromines, *C. gariepinus* and *P. aethiopicus* in the infested areas is attributed to their ability to tolerate low oxygen levels. However, the *Lates niloticus* is very sensitive to low oxygen levels.

**Keywords:** Hyacinth, water quality, fish diversity, abundance

### 1. Introduction

Originally from South America, water hyacinth, *Eichhornia crassipes Solm* is one of the world's most prevalent invasive aquatic plants known to cause major ecological and socio-economic changes in aquatic ecosystems (Center, 1994) [1]. In Africa it was first reported in Egypt between 1879 and 1893 and by 1990s it had spread to every country in the African continent (Center, 1994) [1]. In Kenya, it is believed that water hyacinth entered Lake Victoria in 1989 via the Kagera River, which has its mouth in the Ugandan portion of the lake (Muli, 1996) [2]. It is prevalent in tropical and sub-tropical water bodies where nutrient levels are often high due to agricultural runoff, deforestation, and insufficient wastewater treatment. The weed has a very high growth rate such that it doubles in area within five day (Ntiba et al., 2001) [3]. Nutrients and temperature are considered the strongest determinants for its growth and reproduction (Wilson et al., 2007) [4]. Water hyacinth is mainly found in inshore and shallow areas with minimal disturbances from water currents, hence, Lake Victoria's tropical location, shallow depth and nutrient enrichment provide favourable conditions for its proliferation. The weed's invasion has significant socio-economic and environmental impacts and negatively affects water quality Njiru et al (2002) [5]. Shading of the water by the hyacinth curtails photosynthesis by phytoplankton, while microbial breakdown of decaying plant material uses the available oxygen. The mats reduce dissolved oxygen by restricting the exchange of oxygen across the air/water interface. The oxygen can be reduced to such levels that it can lead to massive fish mortality due to oxygen depletion in the water column (Ochumba and Kibaara, 1989) [6]. Moreover, under anoxic conditions, ammonia, iron, manganese and sulphide

concentrations can rise to high levels deleterious to biota. The weed sometimes block waterways and landing beaches preventing boats from docking, resulting into longer fishing hours, increase in use of fuel and higher fish prices. It can also clog irrigation canals and electricity generating turbines, and cause the spread of water borne diseases to humans. This study investigated the effects of water hyacinth infestation on water quality, fish species diversity and abundance.

### 2. Materials & methods

The main geographical, hydrological and physical characteristics of Lake Victoria and Nyanza Gulf have been summarized by Crul (1995) [7]. This study was conducted within the Nyanza Gulf of Lake Victoria ( $56^{\circ}17'43.01''\text{N}$   $30^{\circ}58'57.32''\text{E}$ ;  $0^{\circ}08'40.7''\text{S}$ ,  $34^{\circ}44'12.4''\text{E}$ ). Sampling areas were selected to compare two areas; water hyacinth infested and non-infested areas. Sampling was done twice a month between October 2014 and March 2015 (using seine net of length 500 m, width 4.0 m, mesh-sizes 2.5- 4.5 inches, with a mosquito net at the end to retain the smaller fish). All the fish species caught were identified to species level and were counted. Water quality parameters (temperature, dissolved oxygen, pH and nitrates) were measured *in-situ*. Shannon diversity index was calculated as follows:

$$H' = - \sum_{i=1}^R p_i \ln p_i$$

Shannon's evenness was calculated using the equation:

$$EH = \frac{H}{H_{\max}}$$

Where  $H$  is diversity,  $EH$  is evenness,  $H_{\max} = \ln S$ ,  $S$  is taxa and  $p_i$  is proportion of species  $i$  relative to the total number.

### 3. Results

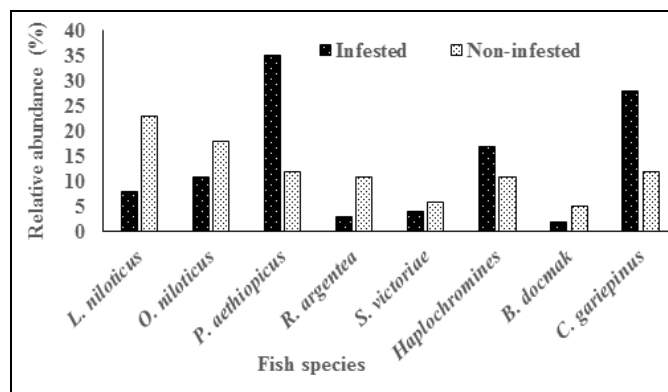
Water quality parameters are presented in table 1. The mean ( $\pm$ SD) temperature of infested areas was  $25.60\pm 4.39^{\circ}\text{C}$  and was slightly higher than that of the non-infested areas ( $24.62\pm 4.94^{\circ}\text{C}$ ). There was no significant difference in temperature between the two areas ( $p>0.05$ ). Dissolved oxygen (DO) of the infested areas had a mean of  $2.44\pm 1.14\text{ mg l}^{-1}$  which was significantly lower than the non-infested areas ( $4.24\pm 0.96\text{ mg l}^{-1}$ ). The mean pH in infested and non-infested areas were  $6.05\pm 1.04$  and  $7.62\pm 0.42$  respectively. The pH differed significantly between the two areas ( $p<0.05$ ). The lowest ( $6.97\pm 0.83\text{ mg l}^{-1}$ ) nitrate value was recorded in hyacinth infested areas and the highest ( $11.34\pm 1.46\text{ mg l}^{-1}$ ) in non-infested areas. There was a significant difference in nitrate concentrations between the hyacinth infested areas and non-infested areas ( $p<0.05$ ). Fish species diversity (2.00) and evenness (0.93) were higher in the infested habitat compared to non-infested areas ( $p>0.05$ ) (Table 2). The water hyacinth infested areas not only had a greater number of individuals present, but the individuals in the community were distributed more equitably among these species. In the infested areas, *P. aethiopicus* (35%) had the highest relative abundance, followed by *C. gariepinus* (28%), whereas in the non-infested areas, *L. niloticus* had the highest relative abundance (23%) followed by *O. niloticus* (18%) (Fig. 1).

**Table 1.** Variation in water quality parameters

Parameter	Infested ( $\pm$ SD)	Non-infested ( $\pm$ SD)	p-value
pH	$6.05\pm 1.04$	$6.97\pm 1.83$	0.03
DO ( $\text{mg l}^{-1}$ )	$2.44\pm 1.14$	$4.24\pm 0.96$	0.01
Temperature ( $^{\circ}\text{C}$ )	$25.60\pm 4.39$	$24.62\pm 4.94$	0.37
Nitrates ( $\text{mg l}^{-1}$ )	$6.97\pm 1.83$	$11.34\pm 1.46$	0.01

**Table 2.** Fish species diversity and evenness

Variable	Infested	Non-infested
Taxa ( <i>S</i> )	8	8
Individuals	218	129
Shannon ( <i>H</i> )	2.00	1.82
Evenness ( <i>EH</i> )	0.93	0.77



**Fig 1:** Relative abundance of the fish species

### 4. Discussion

The slightly higher water temperature observed in the hyacinth infested areas could be attributed to the dense mats which blocked the exchange of heat between the water surface and the atmosphere. This is supported by Navarro and Phiri (2000) [8]. The decaying organic matter from water hyacinth also

generates heat that raises the temperature (Chapman, 1996) [9]. The pH values were generally lower in the hyacinth infested areas than in the non-infested areas. Water hyacinth has been found to stabilize pH levels and temperature in experimental lagoons, thereby preventing stratification and increasing mixing within the water column (Giraldo and Garzon, 2002) [10]. Additionally, decomposition of dead hyacinth releases excess  $\text{CO}_2$  that dissolves in water thus increasing acidity. The reduction in nitrate ion concentrations noted in areas covered with water hyacinth in this study was possibly due to the absorption of these ions by the water hyacinth present in the lake and therefore their consequent high growth rates. Ogunlade (1996) [11] reported that water hyacinth removes nutrients and heavy metals from aquatic environments.

Dissolved oxygen was found to be low under the mats of water hyacinth than in the non-infested areas. This could be attributed to limited photosynthesis beneath water hyacinth mats, and the plant itself does not release oxygen into the water as do phytoplankton and submerged vegetation (Mironga et al., 2011; Meerhoff et al., 2003) [12, 13]. The water hyacinth mats also reduce oxygen concentration by restricting the wind action and exchange of oxygen across the air/water interface (Muli, 1996) [2]. Yongo and Outa (2017) [14] reported low oxygen levels attributed to the frequent occurrence of water hyacinth in the Nyanza Gulf. Dissolved oxygen less than  $5\text{ mg l}^{-1}$  are known to adversely affect function and survival of most fishes, and less than  $2\text{ mg l}^{-1}$  can lead to fish mortality (Chapman, 1996) [9]. In this study the lowest DO concentration recorded was  $1.32$  to  $3.68\text{ mg l}^{-1}$  in the infested areas. Njiru et al (2002) [5] recorded DO as low as  $0.1\text{ mg l}^{-1}$  in the hyacinth area making it inhabitable to most fishes.

Additionally, water hyacinth affects distribution of fish by blocking migratory routes of those escaping low DO and predation (Balirwa et al., 2003) [15]. The water hyacinth has led to the recovery of native fish species more hypoxia tolerant such as catfishes, haplochromines, *P. aethiopicus* and *O. niloticus* (Njiru et al., 2002) [5]. This is because *P. aethiopicus* is obligatory and can breathe atmospheric air, while *C. gariepinus* has an accessory organ that enables it to extract oxygen from the air in waters with low concentration. The *Lates niloticus* mainly inhabit open waters with considerable amounts of dissolved oxygen since it is very sensitive to low oxygen and requires DO levels not less than  $5\text{ mg l}^{-1}$  (Giraldo and Garzon, 2002) [10]. This reason explains why during this study more of *Lates niloticus* were found in the open waters than in infested areas. In terms of species diversity, water hyacinth infested areas generally had a higher diversity of fishes than non-infested areas. Similar results were reported by Meerhoff et al. (2003) [13] where fish abundance and diversity were higher in submerged vegetation, followed by water hyacinth and vegetation-free littoral sites. This is because the water hyacinth provides food, shelter and cover for the fishes (Johnson and Stein, 1979) [16]. The hyacinth also reduces fishing pressure in the intensively infested areas.

In conclusion, water hyacinth mats have altered the water quality of the studied area by reducing the levels of dissolved oxygen. The hypoxic water beneath the mats act as a refuge for more tolerant native species such as haplochromines, *C. gariepinus* and *P. aethiopicus*, while reducing colonisation of sensitive species such as *L. niloticus*.

## 5. References

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