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Evaluation of Growth Rate of Invasive Aquatic Macrophytes and Contribution to Its Use in Organic Fertilizer Production: A Case of *Eicchornia crassipes* (Mart.) Solms, 1883 in the Lobé Creek (Littoral-Cameroon)

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Abstract

From 20 January to 20 July 2023, a study was carried out on the Lobé Creek, a waterway subject to considerable natural and man-made pressures, with a negative impact on its biodiversity and habitats. The aim was to evaluate the growth rate of invasive aquatic macrophytes and their contribution to the use of organic fertilisers: a case of *Eicchornia crassipes* (Mart.) Solms, 1883 in the Lobé Creek (Littoral-Cameroon) with a view to its appropriate use in agronomy. The specific objective was to examine the impact of anthropogenic actions on Lobé Creek, characterise physico-chemical environment of the study area, and evaluate the growth rate of *E. crassipes* and its chemical composition with a view to producing an organic biofertiliser. The results show that *E. crassipes* represents a considerable threat to the populations of these localities. As for the physico-chemical parameters, the temperature values vary from 24 ± 1.41˚C to 26.5 ± 1.13˚C; pH from 6.3 ± 0.1 to 7.2 ± 0.07; conductivity and dissolved oxygen vary respectively from 40.7 ± 1.83 µS/cm to 19.6 ± 3.11 µS/cm and from 7.3 ± 0.14 mg/l to 5.8 ± 1.55 mg/l. Its average growth rate varies from 0.69 feet/day to 0.63 feet/day. With regard to the nitrogen, phosphorus and potassium content of water hyacinth plants, the results show that the average total nitrogen content ranges from 6.11 ± 1.59 g/kg to 5.2 ± 2.03 g/kg; total phosphorus, from 0.52 ± 0.54 g/kg to 0.88 ± 0.38 g/kg; and potassium, from 1.43 ± 0.45 g/kg to 2.61 ± 0.89 g/kg.

Keywords

Eichhornia crassipes, Lobé Creek, Anthropogenic Actions, Physico-Chemical Environment, Growth Rate, Chemical Composition

1. Introduction

Ecological disturbances in an aquatic environment, coupled with growing population growth and the knock-on effect of human activities, have encouraged the introduction and dispersal of a number of species, particularly plant species, some of which have become invasive and harmful to the environment. Biological invasions are considered by many international bodies, including the IUCN, to be the second most important cause of biodiversity loss at international level, just after habitat destruction [1]. *Eichhornia crassipes*, commonly known as water hyacinth, is an invasive aquatic plant native to Amazonia that was introduced in the Congo basin as an ornamental plant for ponds. Observations made in many of Cameroon's rivers, particularly the Moungo, show that they are causing a great deal of ecological, public health and economic damage. Furthermore, the Lobé Creek, tributaries of Moungo, is subject to a number of natural and man-made pressures that are having a negative impact on its biodiversity and habitats. It also appears that *E. crassipes* has almost completely invaded the surface of the water, causing waterways to narrow and reducing fish stocks. The decomposition of the dead leaves makes the environment anoxic, leading to eutrophication of the water and depriving the species in the environment of oxygen. This leads to the asphyxiation of aquatic animals living in areas where water hyacinth proliferates. This alters the physico-chemical and organoleptic quality of the water and reduces fishing stocks. The first initiatives taken to eliminate the plant, by physical (mechanical), chemical or biological means quickly proved to be limited by the speed at which it multiplied. There is therefore an urgent need to find techniques for using water hyacinths that respect the environment in a sustainable way in all its forms. Localized efforts geared towards the removal of aquatic invasive species, like the water hyacinth by the Water Task Group, an NGO based in Douala, proved to be difficult and futile [2]. Different methods have been employed to fight this species, including mechanical, biological and chemical methods. Mechanical methods have by far been employed through mechanical weeding, drainage, clearance, and maintaining removed stocks. Elsewhere, introducing and releasing natural enemies is an environmentally friendly and sustainable approach to controlling of invasive species [3] [4]. Natural enemies including water hyacinth weevils *Neochetina eichhorniae* Warner and *Bruchi Hustache* (Coleoptera: Curculionidae) butterflies have been used to reduce water hyacinth spread by at least 25 % after two years [4]. However, water hyacinth has been shown to be highly effective in a number of areas, including wastewater treatment [2]. Hence, it's used in livestock feed and in the manufacture of art and decorative objects, such as pen holders, bags, animal representations, etc. [5]. Nevertheless, research into its use in livestock feed and agriculture is still very limited. A number of studies have been carried out on the presence of *E. crassipes* in aquatic ecosystems, including one by [6] on the distribution and use of *E. crassipes* in the coastal region of Cameroon. However, the management of water hyacinths in Cameroon's waterways remains a real challenge. Given this state of affairs, we all need to provide information that can help to enhance the value of this aquatic plant. It is in this context that this study was carried out on the rate of growth of invasive aquatic macrophytes and their contribution to the use of biological fertilisers: the case of *E. crassipes* (Mart.) Solms, 1883 in the Lobé Creek (Littoral-Cameroon). The specific objective was to examine the impact of anthropogenic actions on Lobé Creek, characterise physico-chemical environment of the study area, and evaluate the growth rate of *E. crassipes* with a view to producing an organic biofertiliser and its chemical composition, in particular the total nitrogen, total phosphorus and potassium content.

2. Materials and Methods

2.1. Description of the Study Location

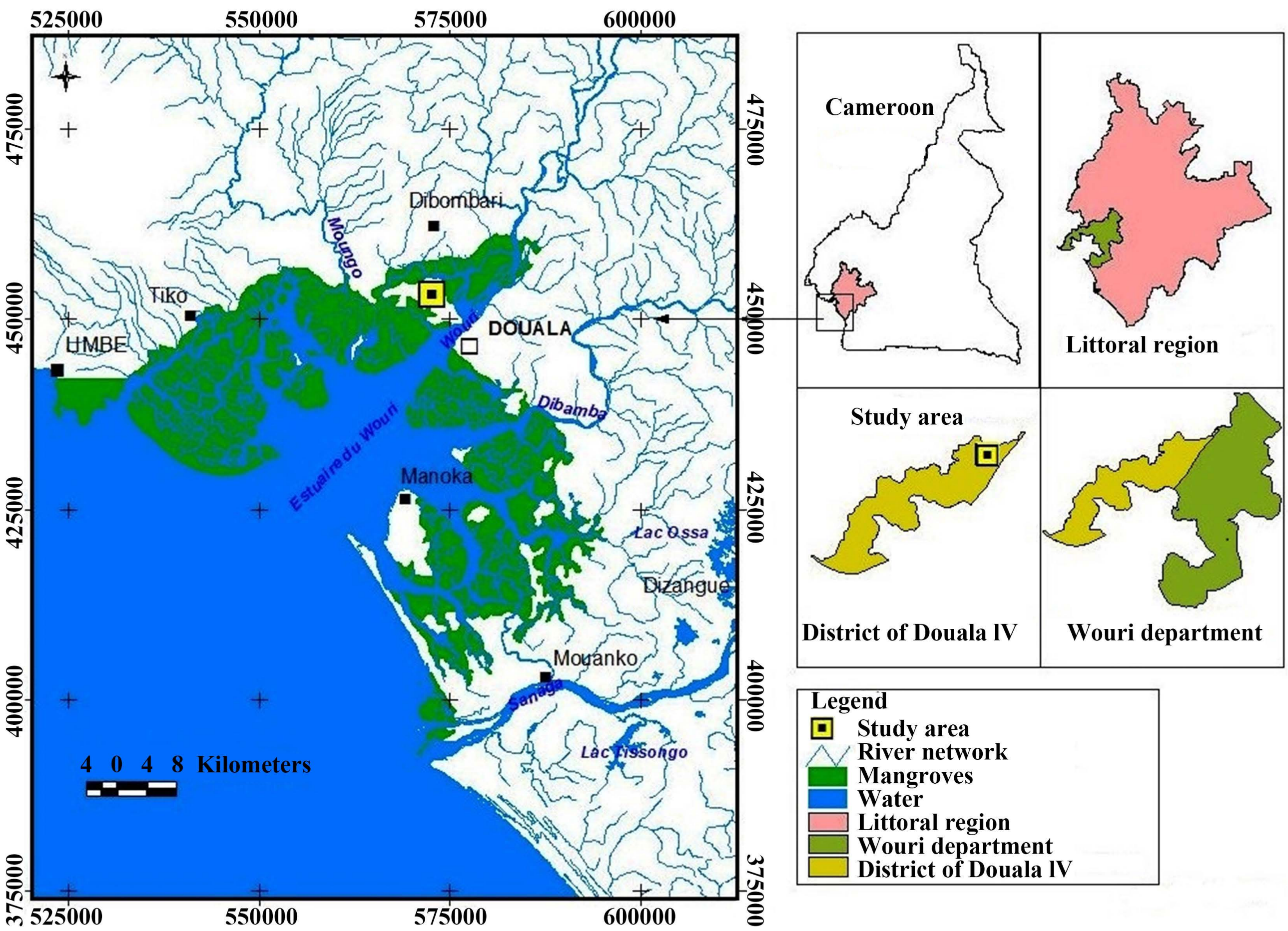


Figure 1. Location of the study area.

The study was carried out in the district of Douala IV in the city of Douala, located in the Littoral region. It lies between 4˚02'53" N and 9˚42'15" E and is bounded to the north by the Moungo department, to the south by the Wouri river, to the east by the Wouri river and to the west by the Fako department (**Figure 1**). The characteristics of the study area are similar to those of the city of Douala as a whole. With an average altitude of 13 m, Douala is subject to an equatorial climate of the Guinean type and Cameroonian sub-type, characterised by two seasons: a nine-month rainy season (March-November) and a short dry season, from December to February [5]. Rainfall is abundant and regular, with annual values ranging from 2.596 mm to 5.328 mm. The air temperature in Douala is relatively high, with a monthly average of around 28˚C [7].

2.2. Data Collection

During both seasons, observations were made of the following physico-chemical and biological parameters:

Floristic surveys of 100 m^2 each were carried out at 2 stations (neighbourhoods 105 and Sodiko Bipélé). Thus, 2 transects of 500 m with 6 quadrats of 100 m^2 each were marked out by wooden stakes fixed in the mud and surrounded by wire netting. To carry out this operation, a semi-open questionnaire was sent to 66 households, specifically those located two rows from each other and close to both banks of Lobé Creek, using a door-to-door strategy.

The pH, temperature, dissolved oxygen, electrical conductivity, suspended solids and total dissolved solids were measured twice a week using a HANNA HI 9829 multi-parameter. Depth was measured using a graduated stake.

The rate of increase was obtained after determining the rate of multiplication of the plants over a period of 50 days. To measure the rate of multiplication of *E. crassipes*, 6 quadras of 100 m^2 were set up in 2 transects, each with a surface area of 100 m^2, marked out by wooden stakes fixed in the mud and surrounded by wire netting. 5 plants of water hyacinth were introduced into each quadra and monitored weekly. This rate of increase was determined using the method described by [8]. Growth rate = (W2 − W1)/(T2 − T1) with W1 = number of plants (or biomass) at the start of the experiment at time T1, W2 = number of plants (or biomass) at the end of the experiment at time T2.

To analyze the nutrient content, in particular Total Nitrogen (TN), Total Phosphorus (TP) and Potassium in water hyacinth plants according to [9] have been use. To do this, a field trip enabled us to collect 100 g samples of fresh plant material. This sampling was carried out on the leaves, stems and roots of water hyacinth taken from each of the stations. They were then dried at a temperature of 105˚C in an oven for 24 hours to constant weight.

Total Nitrogen Content

The method used was the TNT Persulfate Digestion Method using the Hach DR3900 spectrophotometer. Firstly, the digestion reagent solution was prepared by dissolving sachets of TNT persulphate digestion reagent powder in distilled or deionised water. The sample was then prepared by measuring an appropriate quantity and transferring it to a TNT digestion vial (the blank prepared with distilled water). The digestion reagent solution was then added to each vial, which were then hermetically sealed. The vials were then placed in a digestion block set at 100˚C for 2 hours to allow digestion to take place. After the digestion period, the vials were cooled to room temperature. Finally, the contents of each vial were mixed by gentle inversion and an appropriate aliquot of the digested sample solution was transferred for analysis using the Hach DR3900.

Total Phosphorus Content

Phosphorus was determined using the "molybdovanadate" Method. 1 ml of molybdovanadate reagent was added to each water sample and to a control (distilled water). The orthophosphate molecules present reacted with the molybdate in an acid medium to form the phosphomolybdate complex. In the presence of vanadium, an acid called vanadomolybdophosphoric acid is formed and takes on a yellow colour. The intensity of the colour is proportional to the concentration of phosphates present in the medium. The reading was recorded on a Hach DR/3900 spectrophotometer and the values were displayed as orthophosphate (PO_4^{3-}), expressed in mg/L. These values were then multiplied by 0.3261 to give P.

Potassium Content

To 25 ml of sample contained in a test tube, the contents of a potassium 1 and potassium 2 reagent capsule were added successively. The contents were then capped and turned several times to mix. As soon as the solution was clear, the contents of one capsule of potassium reagent 3 were added, and then shaken for 30 seconds. The solution obtained was poured into a 25 ml cell. Another cell (the blank) was filled with 25 ml of sample. Finally, the reading was taken with a DR/3900 spectrophotometer at a wavelength of 650 nm and the result was expressed as mg/l potassium.

2.3. Data Analysis and Interpretation

The parameters studied were subjected to descriptive analysis using Microsoft Excel 2013. The results obtained were represented exclusively using graphs and curves.

3. Results

3.1. Impacts of Human Activities on Lobé Creek

The distribution of activities carried out around the watercourse shows that 9.38% of the population practice agriculture. The same applies to livestock farming. In addition, 6.25% of local residents fish, while 25% engage in other activities, such as mechanics, welding and trade. Finally, 50% do not engage in any activity whatsoever (Figure 2).

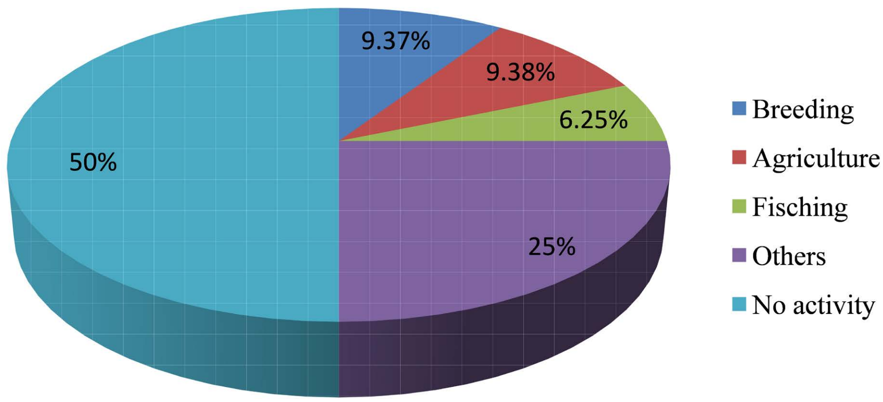


Figure 2. Breakdown of activities around Lobé Creek.

Most people who farm do not improve the quality of their soil. Of those who do, 90.91% use no soil improvers at all. Of the remaining 9.09%, 6.06% use chemical fertilisers, while the rest (3.03%) use only natural products, including pig faeces, chicken droppings, household waste and ashes (Figure 3).

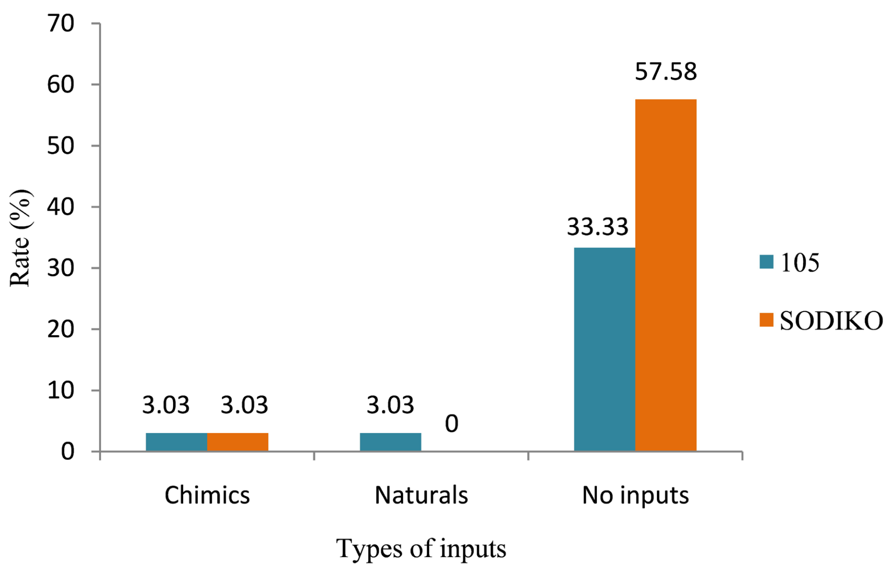


Figure 3. Rate of input use by district.

People's Perception of *E. crassipes*

According to the survey results, *Eichhornia crassipes* is gradually invading the creek's watercourse and becoming a nuisance for the surrounding population; for 60.61% of households, *Eichhornia crassipes* is a nuisance plant. On the other hand, around 18.18% perceive it as useful for the landscape and the environment, while 21.21% have no interest in the plant (Figure 4).

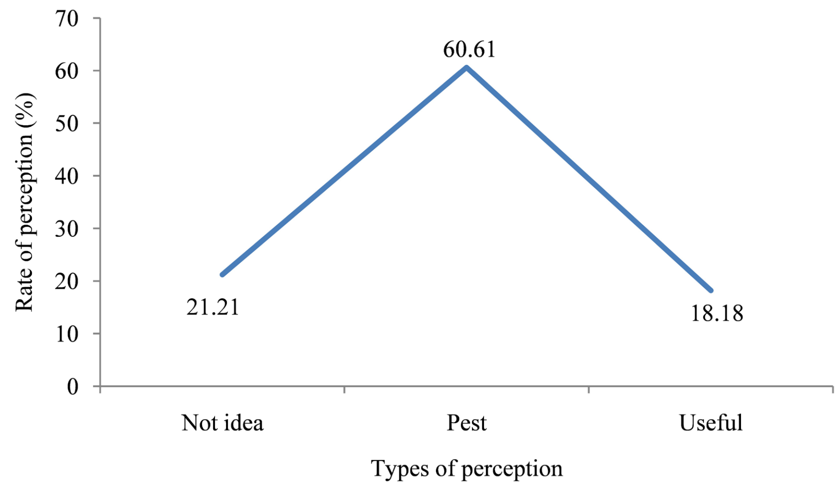


Figure 4. Perception of the presence of *E. crassipes* by the populations.

3.2. Characteristics of the Aquatic Environment in Lobé Creek

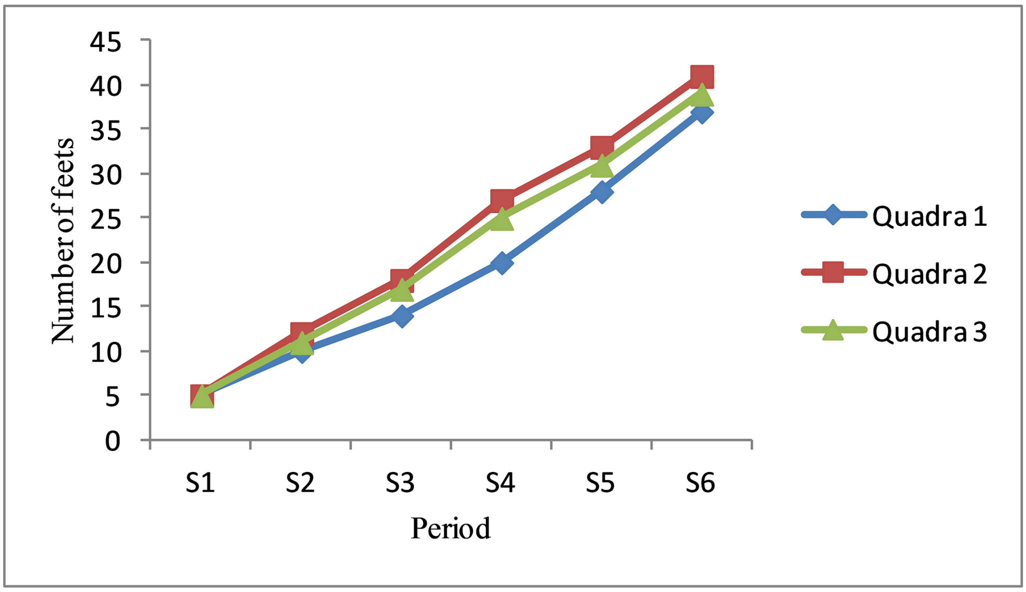
The physico-chemical parameters of the water in the creek vary from station to station. At Station 1, located upstream, conductivity and dissolved oxygen are the highest (conductivity 40.7 ± 1.83 µS/cm; dissolved oxygen 7.3 ± 0.14 mg/l) compared with Station 2, where they are low (conductivity 19.6 3 ± .11 µS/cm ; dissolved oxygen 5.8 ± 1.55 mg/l); on the other hand, pH and temperature are higher at Station 2 (pH 7, ±20.07; temperature 26.5 ± 1.13˚) than at Station 1 (temperature 24 ± 1.41; pH 6, ±30.14). Depth was greater at Station 2 (1.95 ± 0.21 m) (**Table 1**).

Table 1. Physico-chemical parameters of the water in Lobé Creek.

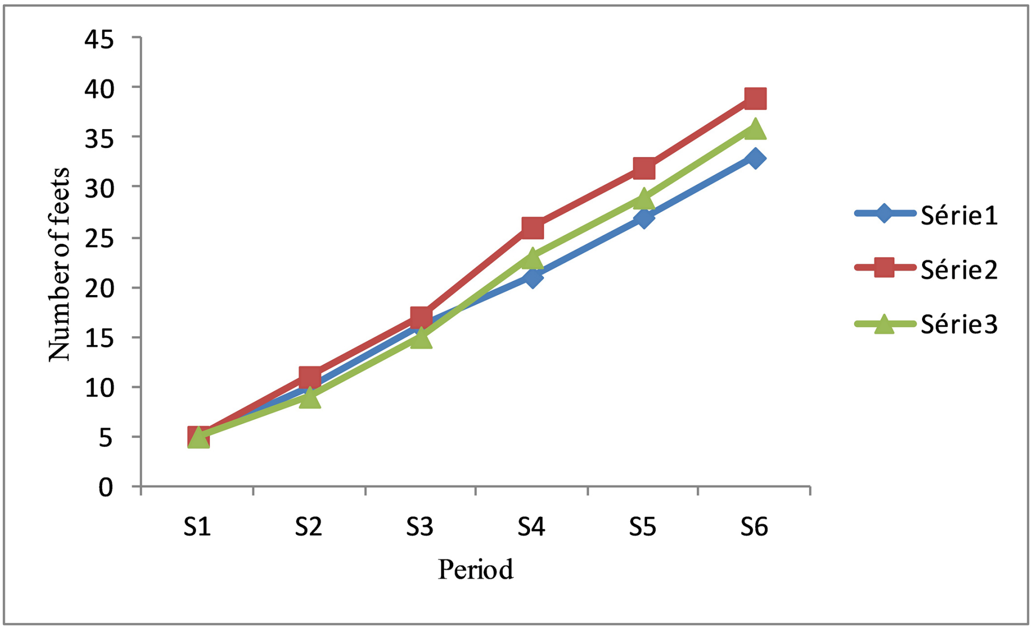
Parameters	Station 1	Station 2
pH	6.3 ± 0.14	7.2 ± 0.07
Temperature (˚)	24 ± 1.41	26.5 ± 1.13
Conductivity (µS/cm)	4.07 ± 1.83	19.6 ± 3.11
Oxygène dissout (mg/l)	7.3 ± 0.14	5.8 ± 1.55
Profondeur (m)	1.6 ± 0.49	1.95 ± 0.21
TDS (mg/l)	190 ± 63.63	160 ± 6.57
MES (mg/l)	199 ± 15.55	130 ± 3.53

3.3. Growth Rate of *E. crassipes*

With regard to the rate of growth, an accelerated rate of growth was observed, particularly at Station 1, with a total of 41 stems at quadra 2, 39 stems at quadra 1 and 37 stems at quadra 3 (**Figure 5(a)**). At Station 2, on the other hand, where stems are least represented, the number of plants varies from 33 to 39 stems, with 33 stems in quadra 6, 36 stems in quadra 4 and 39 stems in quadra 5 (**Figure 5(b)**). The average growth rate of *E. crassipes* was 0.69 feet/day at Station 1 and 0.63 feet/day a Station 2.



(a)



(b)

Figure 5. Proportion of multiplication of *E. crassipes* over time: (a) Station 1 and (b) Station 2.

3.4. Chemical Composition of *E. crassipes*

With an overall average of 5.65 ± 0.45 g/kg on Lobé Creek, the Total nitrogen content decreases from upstream to downstream. A value of 6.11 ± 1.5 g/kg was recorded at Station 1 and 5.20 ± 2.03 g/kg at Station 2 (**Figure 6**).

Total phosphorus and potassium levels vary from station to station, with overall averages of 0.83 ± 0.44 g/kg for total phosphorus and 2.02 ± 0.5 g/kg for potassium. Unlike Station 1, Station 2 has the highest levels, with 0.88 ± 0.38 for total phosphorus and 2.61 ± 0.89 for Potassium (**Figure 6**).

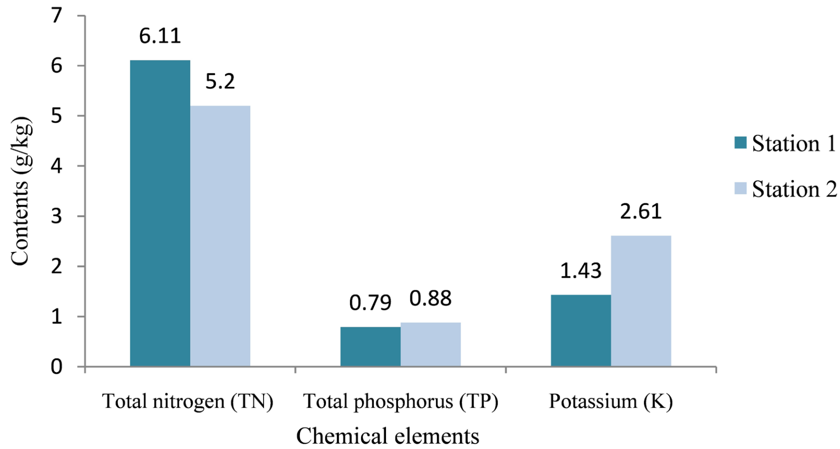


Figure 6. Total of NPK content in *Eichhornia crassipes* plants.

4. Discussion

4.1. Effects of Human Activities on Lobé Creek

In the Sodiko and 105 neighbourhoods, according to the local people, *E. crassipes* has a considerable impact on the environment. Fishing is the least common activity (6.25%), while 25% of households carry out several other activities, including trading, mechanics, welding and hairdressing. Furthermore, half of the population surveyed does not carry out any activities at all. This situation could be explained by the fact that fishing is hampered by the proliferation of *E. crassipes*, which deprives people who live from fishing of their activity, forcing them to turn to other activities. In addition, these households (60.61%) perceive the water hyacinth as a harmful and dangerous plant for their environment, since it contributes considerably to the degradation of the aquatic ecosystem through the reduction in stocks of fish products and, at the same time, encourages the introduction of reptiles into their homes and the development of various diseases. On this subject, [10] concluded from a study that this plant encourages the development of diseases such as malaria and bilharzia.

4.2. Physico-Chemicals Characteristics of Lobé Creek

In contrast to Station 1, depth, pH and temperature have higher values at Station 2, while conductivity, Total Dissolved Solids, Suspended Solids and Dissolved Oxygen are high at Station 1. The high temperatures recorded at Station 2 (26.5 ± 1.13˚C) are thought to be due both to the evapotranspiration of *E. crassipes* in the creek and to its ongoing degradation process, which releases heat. In this regard, according to [11], the average water temperature of Lake Ravelobe invaded by Water Hyacinth was equal to 26.33 relative to the sampling period. In addition, the presence of silt formed by the decomposition of *E. crassipes* plants on the one hand, and by the accumulation of sediments on the other, could explain the shallow depth (1.6 ± 0.49) at Station 1. As for dissolved oxygen, the low dissolved oxygen values at the stations could be explained by the fact that decomposition of the *E crassipes* plants consumes most of the oxygen available at these sites; also, the plant cover formed by the water hyacinth would reduce oxygen exchange at the air-water interface and at the same time reduce light penetration. As for pH, it varies slightly at the two stations. Station 1 has a neutral pH (6.3 ± 0.14) and Station 2, an acid pH (7.2 ± 0.07); this would be due to the regular decomposition of the water hyacinth, the increase in biological activity, associated with external inputs which would lead to a considerable drop in oxygen and consequently an enrichment in CO_2 which would influence the acid-base balance and thus make the environment acidic.

4.3. Growth Status of *E. crassipes*

At the end of this study, it emerged that *E. crassipes* is developing at an exponential rate in Lobé Creek, with a growth rate of 0.69 feet/day for Station 1 and 0.63 feet/day for Station 2, relative to the environmental conditions that would be favourable for its development. On this subject, according to studies carried out by [12], the very low growth rate of water hyacinth in the Bangr-wéoogo urban park of 0.083 feet/day is due to the difference in season and spatial situation. Priso *et al.* (2016), on the subject of the growth rate of this plant, concluded that the observation of the growth rate of the water hyacinth shows that it is likely that almost the entire river Wouri and its tributaries will be invaded within a decade if nothing is done.

4.4. Chemical Composants of *E. crassipes*

Micronutrient analysis of the leaves, stems and roots of *E. crassipes* shows that this plant, harvested in Lobé Creek, has high levels of nitrogen. This analysis shows that nitrogen levels are higher in Lobé Creek, particularly at Station 1 (6.11 ± 1.5 g/kg); this can be explained by the presence of human activities around the watercourse and by the process of enrichment of the watercourse by effluents. Furthermore, the phosphorus and potassium values are not very significant, with a maximum equal to Station 2 (0.88 ± 0.38 g/kg for phosphorus and 2.61 ± 0.89 g/kg for potassium). In view of the results obtained, water hyacinth could be a source of raw material for the manufacture of compost to enrich soils [13]. Furthermore, [14], following a study in Vietnam, obtained results lower than those of this study, with N, P and K contents equal to 2.30 for nitrogen, 0.28 for phosphorus and 2.67 for potassium.

5. Conclusions and Recommendations

This study shows that there is a strong influence both on populations, and particularly on fishing activity, and on the aquatic ecosystem. In terms of growth rate, it was found that *E. crassipes* has a strong ability to multiply, with a higher average growth rate upstream of 0.69 feet/day. In addition, nutrient levels (nitrogen, phosphorus and potassium) were assessed in the plant, with phosphorus and potassium values being higher both upstream and downstream. In view of the above, *E. crassipes*, a threat to aquatic ecosystems, represents an opportunity for the development of agriculture and livestock farming.

According to some authors, the following plan is recommended to help ensure appropriate management of Lobé Creek:

- Mechanical removal of the plant from watercourses heavily colonised by *E. crassipes* [15] [16];
- Regular clearing and clear-cutting of the species present around watercourses for permanent control [17];
- Keeping and storing plants uprooted from the water several metres from the bank, not only to prevent them from returning to the watercourses, but also to make compost to enrich the soil or to use as animal fodder [18];
- Popularise the potential of *E. crassipes* as a valuable species in agriculture, and livestock farming...

6. Policy Implications and Future Areas for Research

The impact of human activities on the environment, and in particular on aquatic ecosystems, must be a matter of concern and supported by evidence. This is particularly important and visible in communities located close to lotic or lentic ecosystems around which populations settle. It is essential to recognise that the sustainable management of these environments is essential to the survival of our planet through the stable coexistence of man and the resources to which he has access. To achieve this, it is necessary to use environmental management methods, particularly for flora. To achieve this, it is necessary to use both scientific and sustainable political management tools that take into account socio-economic, cultural and political aspects. Raising the awareness of the surrounding communities by raising awareness of waste management, environmental conservation and the value of invasive aquatic plants, particularly *E. crassipes*, is crucial to the survival of these environments. And once all the stakeholders are collectively committed to sustainable management efforts, this becomes a key factor in ensuring the survival of animal and plant life. It is therefore important to take into account the attitudes and perceptions of the communities surrounding aquatic ecosystems with regard to their coexistence with the environment, because these communities often consider macrophytes to be problem plants due to their invasive nature for the majority. This apprehension manifests itself in the systematic destruction of these plants, to the detriment of the potential they could offer.

In view of the above, it would be useful to promote a new approach to the sustainable management of aquatic ecosystems through the use of some of these plants, notably *E. crassipes*. Lastly, awareness campaigns and the introduction of local people to the activity of transforming invasive aquatic plants, including the water hyacinth, into agricultural inputs are all the more important as they help to preserve the integrity of aquatic ecosystems and also make it possible to improve the productivity of agricultural land.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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