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Effects of water hyacinth *Eichhorniacrassipes* (Mart.) Solms-Laubach treatment with sodium chloride on aquatic biological communities of a semi- artificial system

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Abstract
This study was conducted to evaluate the impacts on aquatic biological communities (plankton, macroinvertebrates) induced by the application of sodium chloride in control of water hyacinth *Eichhorniacrassipes*. For this purpose, an experimental device consisting of a pond containing hyacinth plants (2/3 of the surface) and a spraying system were used. Sea water of 24.68 g/ L NaCl was used to spray hyacinth plants for one day. Plankton (phytoplankton and zooplankton) were evaluated before the start of the test and every 5 days after application of the saline solution while benthic macroinvertebrates were only evaluated at the beginning and end of the experiment in areas covered and not covered by water hyacinth. Note that phytoplankton biomass was estimated by assaying chorophyll a. The results obtained show that in free water the concentration of chlorophyll a has increased from 0.02 to 0.32 mg/L; this rose from 0.01 to 0.23 mg / l in hyacinth water. The diversity and density of zooplankton decreased from 16 to 6 and from 85 to 42 individuals per liter respectively in free water and in hyacinth water. On the other hand, those of macroinvertebrates increased from 173 to 425 and from 418 to 999 respectively in free water and in hyacinth water.

1. Introduction

Aquatic invasive plants pose a particularly acute problem in tropical and intertropical areas. The growth of these weeds is extremely rapid, allowing them to develop very large populations in areas where they were not even reported a few years ago. Of the many aquatic plants encountered, water hyacinth cause serious problems because of its abundance and rapid development [1]; [2]; [3]. Indeed, this plant may threaten the diversity of local native species and alter the physical and chemical aquatic environment, there by altering the structure and functioning of the ecosystem by disrupting food chains and the nutrient cycle [4]; [5]; [6]; [7]; [8]; [9]; [10]. In addition to this environmental problem, the invasion of the water bodies by this plant negatively impacts the economic returns of the fishery by the decrease of the catches but also the human health by constituting an environment favourable to certain diseases related to the water (malaria, schistosomiasis) [11]. In Africa, this plant was reported for the first time in the Nile Delta and South Africa, Natal, and Southern Rhodesia (Zimbabwe) in 1937 [12]. In Ivoiry coast, the invasion of the lagoon area was very rapid, apparently beginning in the eastern Ebrié lagoon and in the lower course of the Comoe River, and subsequently spreading to other parts of the lagoon [13]. Its extension began in Benin from northern Nokoué Lake fed by the Sô River, Ouémé River, Azili and Célé lakes [14]. According to [15], water hyacinth can be found from the south to the north, with the exception of coastal lagoon, lake Ahémé, the low valleys of Mono and the south-west of territory. Several methods of fighting against this plant have been adopted but none of them has resulted in a satisfactory result. These are of course the physical fight (manual and mechanical) which consist in manual removal of plants as well as using heavy equipment [16]; chemical fights based on the use of herbicides [17]; [16]; biological struggles based on the use of natural enemies (insects, aquatic herbivores) of the plant in order to create permanent pressure on it [18]. However, salinity generally limits the establishment of the species in coastal and estuarine areas [19]. The fight against water hyacinth by transfoliary spray of concentrate based on sodium chloride (NaCl); this at high doses leads to significant lesions marked mainly by the folding and yellowing of the leaves thus announcing the leaf necrosis and therefore the mortality of the plant [20].The objective set by this study is to evaluate the impact of this control technique on the biological quality of water.

2. Material and Methods

2.1. Device and experimental procedures

The experiment was realised in situ on a pond of 33 m2 of area of Wetlands Research Laboratory of the Faculty of Science and Technology (FAST) of Abomey-Calavi University (Benin). The pond was planted with hyacinth plants on 2/3 of its surface. The remaining 1/3 consists of free water. The volume of water contained in the pond was initially (before spraying) estimated at 341 m3 of water. The spraying device consists of a compressor machine of 50 bar pressure surmounted by a link and connected to spraying pistol water. This pistol is equipped with a jar with a capacity of 0, 5l of water. The foliar system of hyacinth plants produced in situ was sprayed by seawater with a salinity of 24, 68g/L during a day. The quantity of sea water sprayed at m2 was 11.32 L. Immediately after spraying, we observe a folding of the leaves; three (03) to four (04) days after spraying, there is yellowing which announces the necrosis of the leaves and thus the mortality of the plant. The volume of water remaining in the pond after the experiment is 13.6 m3. The study of the impact of this control technique on the biological quality of the water was realized by evaluation of planktonic population (phytoplankton and zooplankton) and that of the benthic macroinvertebrates before and after spraying of the plants. Zooplankton and phytoplankton densities were measured before spraying, immediately after spraying, and every five days after spraying over a period of 25 days (25 days), while that of macroinvertebrates was evaluated at the beginning and at the end of the experiment.

2.2. Study of the phytoplankton population

For phytoplankton population study, we proceeded to the estimation of the algal biomass which passes by the determination of chlorophyll a. Thus, 150 ml of water of each sample was filtered using the vacuum pump MILLIPORE type XF54 230 50 and Whatman type filter paper of 0.45 microns mesh. After filtration, the filter paper is folded and placed in a test tube containing 5 mL of acetone methanol (5/1) which is then placed in a water bath at 65 °C for 2 minutes to facilitate extraction. Absorbance of the extract was then measured spectrophotometrically at 665 nm and 750 nm, before (Aa) and after acidification (Ap) with 0.1 N hydrogen chloride (HCl).The calculations were made using the formula derived from the equation below:

$$Ca=27*[(Aa\ 665-Aa\ 750)-(Ap\ 665-Ap\ 750)]*v/(L*V)$$ [21];

where Aa 665 &Aa 750=Absorbances at 665 and 750 nm before acidification; Ap 665 & Ap750= Absorbances at 665 and 750 nm after acidification; v = Volume of solvent used for extraction in milliliters; V= Volume of filtered water in Liters; L= Optical path of the tank used in centimeters; 27= Experimentally determined factor.

2.3. Study of the zooplankton population

Zooplankton populations were evaluated before and after plant spraying. Thus, a volume of 20 L of water was filtered using plankton net of 100µm. Once formol-fixed (5%) samples were collected in sterile vials and stored before observation. Zooplankton organisms have been identified from the guide of [22]; [23]. The zooplankton density was estimated from the following formula:

$$D = [(N/V1) * (V2/V3)] /V3$$ [24]

where D= zooplankton density; N= number of individuals counted; V1= volume observed (L); V2 = concentrated volume (L); V3 = Filtered Volume (L).

2.4. Study of benthic macroinvertebrates population

For the study of the benthic macroinvertebrate population, sampling was realized with a 200 µm mesh net [25]. The formol-fixed samples (5%) were stored in 0.75L bottles and returned to laboratory for sorting. In laboratory, samples kept in labelled containers were rinsed abundantly with clear water following a series of sieves with a decreasing mesh size (500 to 200 µm) to eliminate the remaining fine substrate and the elements coarse (gravel, plants, leaves...). By delicately manipulating the organisms, using fine forceps in petri dishes, sorting and identification were done with a binocular magnifying glass. This same tool as well as an optical microscope was used for the determination and counting of organisms (total number of taxa counted, number of individuals per taxon). The organisms have been identified at the family level. Those taken into consideration are found in larval, nymph, and adult form. Note that the volume of water explored is estimated at 19 dm3. The determination of the harvested specimens was realised by using of books, collections and guides for the determination of macroinvertebrates as “Guide to the Identification of Quebec's Principal Freshwater Benthic Macroinvertebrates” [26]; “Taxonomic Guide to Maghreb Freshwater Oligochaeta” [27]; and “freshwater invertebrates” [28].

2.5. Statistical analyzes

Analysis of the ANOVA variance was performed using the STATISTICA version 6 software) in order to see the significant differences between the average values of the chlorophyll a concentration and the different groups of zooplanktons obtained in open water and in hyacinth water.

3.Results and discussion

3.1. Results

3.1.1. Impact on the phytoplankton population

Chlorophyll a concentration varied from 0.02 ± 0.00 to 0.32 ± 0.01 mg/l with an average of 0.10 ± 0.12 mg/l in water free hyacinth. In hyacinth water we have a chlorophyll a concentration between 0.01 ± 0.00 mg/L to 0.23 ± 0.07 mg/l and the mean is 0.09 ± 0.10 mg/L (figure 1). Average value of chlorophyll obtained in free water is higher than that of the medium covered by hyacinth. Analysis of variance indicate no significant difference between the levels of chlorophyll a obtained in two mediums (p>0,05).

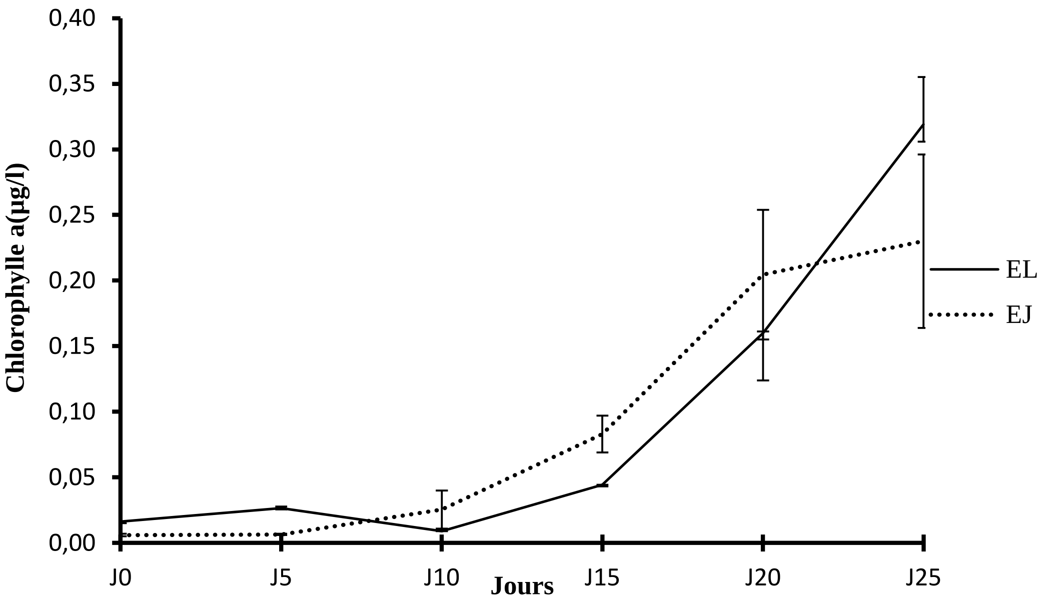


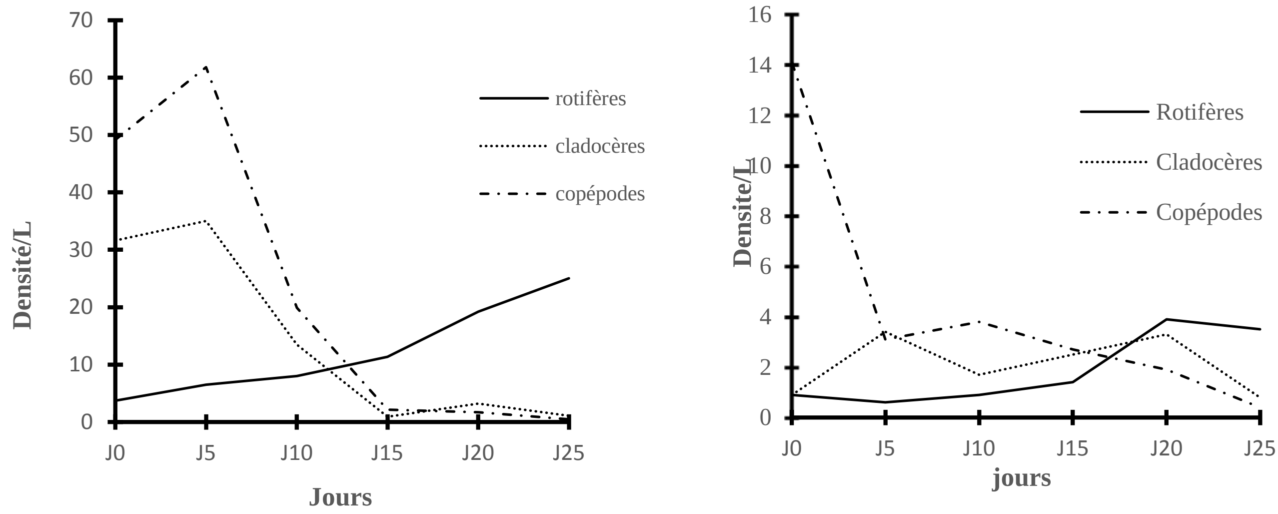
Fig1: Variation of chlorophyll a concentration in free water (EL) and in water covery (EJ) by water hyacinth during the test

3.1.2. Impacts on the zooplankton population

In hyacinth water, copepoda density was initially (before spraying) estimated at 49 individuals per liter. Their population increased until the 5th day after spraying, reaching a value of 62 per liter, but from the 5th day it fell to a value of 01 per liter at the end of the test (Figure 2A). In free water, this same density initially estimated at 14 individuals per liter decrease until disappearing from the medium (Figure 2B).

The density of cladocera, which was initially estimated at 32 individuals per liter, also increased to 35 individuals per liter at the 5th day after spraying, but decreased by one (01) per liter at the end of the tests in hyacinth water (Figure 2A). In free water, this density has increased from 1 to 3 individuals per liter (Figure 2B).

Rotifera densities increased from the beginning to the end of the experiment in two mediums. In sum, the diversity and density of zooplankton decreased significantly ($p < 0.05$) from 16 to 6 and from 85 to 42 per liter respectively in free water and in hyacinth water.



A

B

Figure 2: Evolution of zooplankton density in hyacinth water (A) and free water (B).

3.1.3. Impact on benthic macroinvertebrates population

Table below summarizes individual number as well as the different benthic macroinvertebrate taxa recorded at the beginning and at the end of the experiment.

Table 1: R epresentativity rate of the different groups of macroinvertebrates harvested at the beginning and at the end of the test.

			hyacinth water		Free water	
			Before spraying	After spraying	Before spraying	After spraying
Insects	**Dipteres**	Chironomidae	12.32	0.10	1.15	-
		Ceratopagonidae	-	-	-	0.47
	Odonates	Libellulidae	-	0.75	2.89	0.24
	Plécoptères	Leuctridae	-	0.20	-	-
	Trichopteres	Hydropsychidae	-	0.05	-	-
Not-insects	**Basommatophores**	Physidae	0.36	-	-	-
		Lymnaeidae	-	0.15	-	-
		Planorbidae	-	0.05	-	-
	Mésogastéropodes	Hydrobiidae	87	98.50	95.95	99.29

At the beginning of the experiment (before spraying), 418 macroinvertebrate individuals were collected in hyacinth water. Only three (03) families namely Chironomidae, Physidae, Hydrobiidae belonging respectively to the orders of Diptera, Basommatophores and Mesogasteropoda are represented. At the end of the test, 999 macroinvertebrate individuals were collected. Seven (07) different families were identified namely: Chironomidae, Libellulidae, Leuctridae, Hydropsychidae, Lymnaeidae, Planorbidae and Hydrobiidae belonging respectively to the orders of Diptera, Odonata, Plecoptera, Trichoptera, Basommatophores and mesogasteropoda. This population of benthic macroinvertebrates is largely dominated by not-insects individuals (mollusqua) which represent 87.36% (Figure 3) and 98.70% (Figure 4) respectively before and after spraying.

At the beginning of the experiment, 173 individuals of macroinvertebrates were collected in free water. Three (03) families are also represented. These are Chironomidae, Libellulidae and Hydrobiidae belonging respectively to the orders Diptera, Odonata and Mesogasteropoda. At the end of the test, only three (03) families were collected namely Ceratopagonidae, Libellulidae and Hydrobiidae which belong respectively to the orders of Diptera, Odonata and Mesogasteropoda. This population of benthic macroinvertebrates is also dominated by not-insects individuals (mollusca) which represent 95.95% (Figure 5) and 99.29% (Figure 6) respectively before and after spraying.

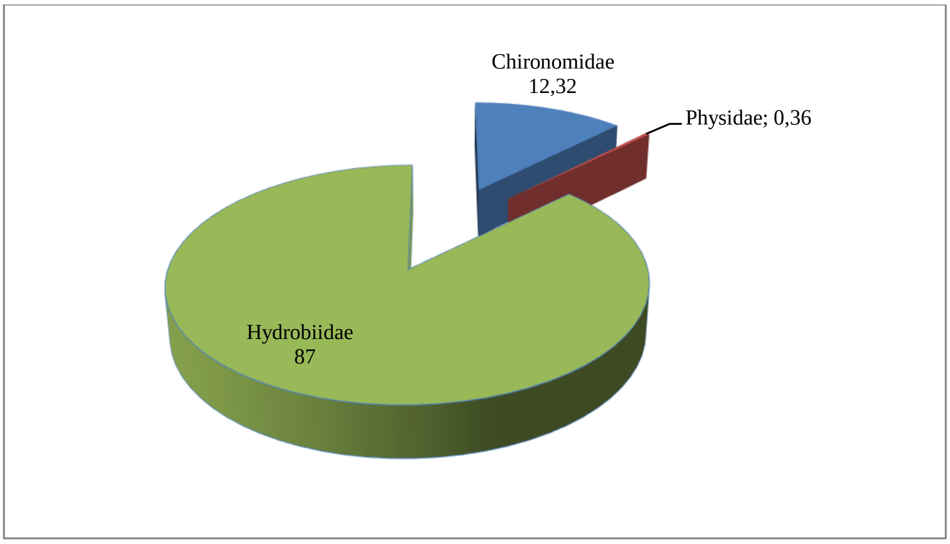


Figure 3: Representativity rate of the different groups of macroinvertebrates harvested in hyacinth water at the beginning of the experiment.

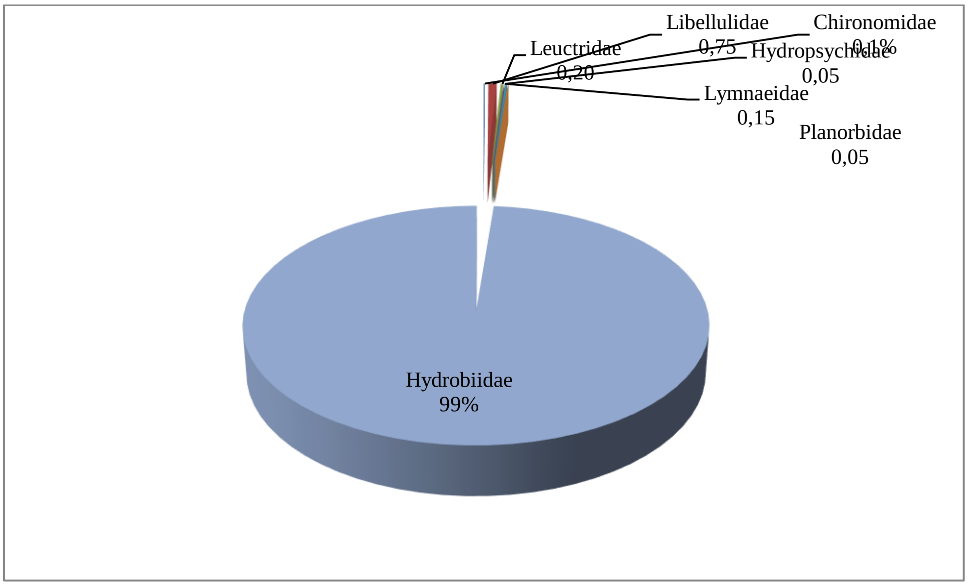


Fig4: Representativity rate of different groups of macroinvertebrates harvested in hyacinth water at the end of the experiment

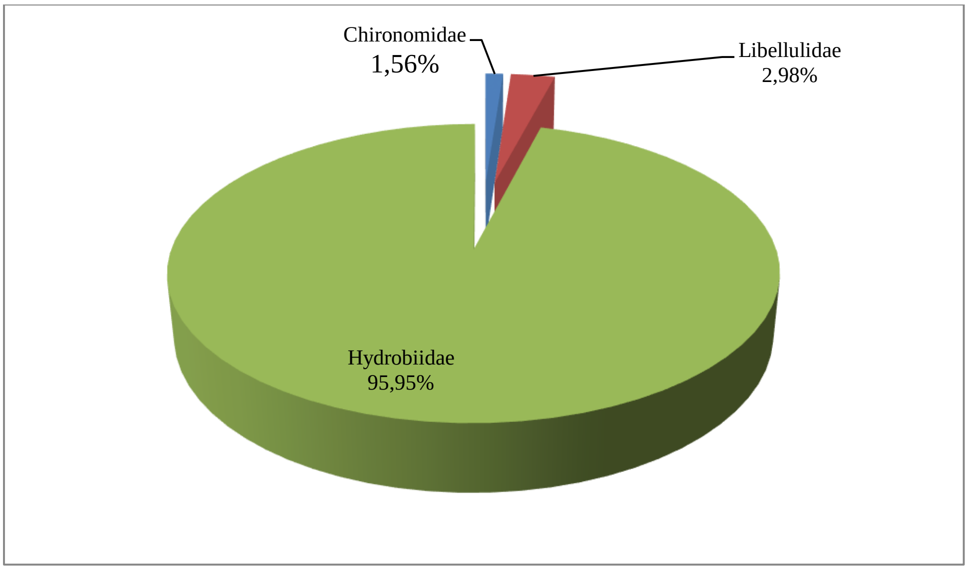


Figure 5: Representativity rate of the different groups of macroinvertebrates harvested in free water at the beginning of the experiment

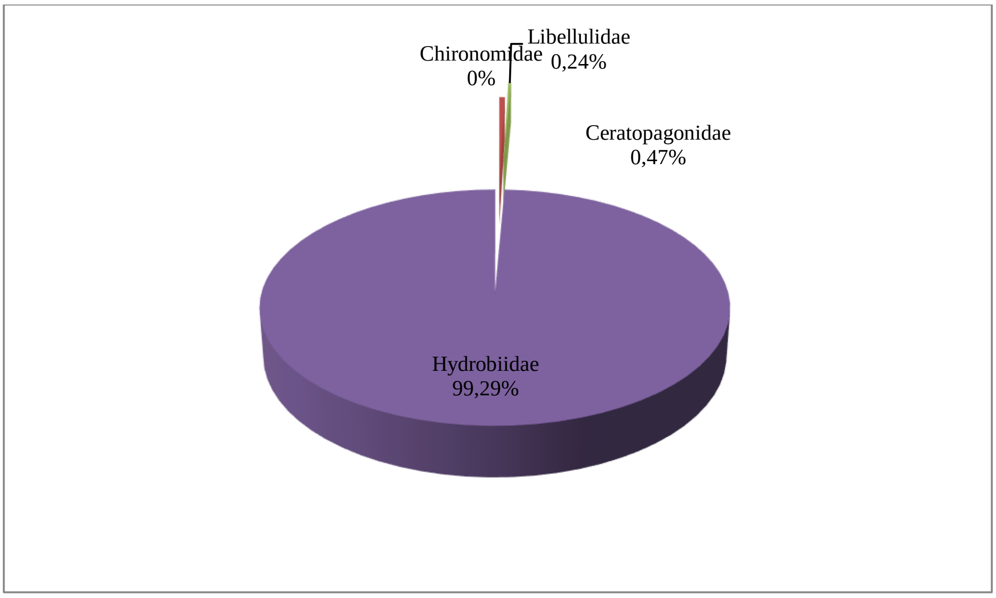


Figure 6: Representativity rate of different groups of macroinvertebrates collected in free water at the end of the experiment

3.2. Discussion

3.2.1. Impacts on Plankton

In free water as well as in hyacinth water we noted an increase in chlorophyll a which is therefore reflected in an increase of the algal biomass in the mediums. On the other hand, the zooplankton density decreased from 85 individual/L at the beginning of the experiment to 42 individual/L in hyacinth water and from 16 to 6 individual /L in free water. Our results corroborate those obtained by [29]; who used other types of herbicides (diquat and 2,4-D amine) to spray hyacinth plants that had invaded the dam reservoir located in the metropolitan area (Mexico City). Eliminating target of hyacinth plants was achieved, but they observed after spraying a high production of algae and a decrease in production of the medium in zooplankton after the decomposition of hyacinth plants. Indeed, the gradual disappearance of the medium of the copepoda; excellent indicators of unpolluted water [30]; giving place to rotifera (organisms capable of resisting advanced eutrophication except for some species) [31];[32];[33];[34];) tells us about the beginning of eutrophication of the medium. This eutrophication of the environment is nothing other than the consequence of a strong production of organic matter resulting from the decomposition of hyacinth plants because of the decrease of the volume of water in the medium. The abundance of zooplankton populations is not unrelated to the abundance of organic matter, and the amount of nutrient salts is to some extent responsible for the development of algal populations [35]. The increase in the production of phytoplankton could be justified by the mineralization of the organic matter resulting from the decomposition of hyacinth plants in the environment.

3.2.2. Impacts on the benthic macroinvertebrate population

In hyacinth water, 418 and 999 macroinvertebrate individuals were respectively collected at the beginning and at the end of the experiment. In free water, 173 individuals of macroinvertebrates were also collected at the beginning and 425 individuals at the end of the test. The appearance of new macroinvertebrate taxa after spraying, especially in hyacinth water, has been noted. These results confirm the work done by [36] in two reservoirs of the New Year River in South Africa. They observed the negative effect of *Eichhornia crassipes* on the abundance and diversity of benthic macroinvertebrate communities, mainly marked by the disappearance of two large groups of insects in the presence of this plant, the Ephemeroptera and Heteroptera, as well as a sharp decrease in the occurrence and average abundance of all other faunal groups, especially Diptera.

In fact, a disturbed watercourse can create unfavorable conditions for certain organisms thus giving place to other more tolerant organisms [37]. The analysis of the whole population harvested during the study shows that mollusca are numerically the most inventoried and are represented by Hydrobiidae. In addition, most individuals harvested at the beginning of the test in free water and in water covery by hyacinth except for Chironomidae (pollutants) have all moderate tolerance to pollution.

After spraying, in water covery by hyacinth we noted the appearance of new taxa represented by Libellulidae, Leuctridae, Hydropsychidae, Lymnaeidae, Planorbidae and especially the multiplication of Hydrobiidae mollusca that feed on decomposing plant debris [38]. Their presence would be due to the decomposition of dead leaves of hyacinth in the medium.

In addition, dead hyacinth plants after decomposition form a carpet and settle on the bottom of the water and cover the mud. Still after spraying, the density of Chironomidae decreased from 12.32% to 0.10% in hyacinth water but disappeared in open water. The low rate of Chironomidae obtained at the end of the tests could be justified that they would have been buried in the sediment and could not be found in large numbers because of the carpet formed by dead hyacinth plants after decomposition

Conclusion

The study of the impacts on aquatic biological communities (plankton, macroinvertebrates) induced by the application of sodium chloride in the fight against the water hyacinth Eichhornia crassipes reveals on the one hand an increase in the production of the medium in phytoplankton. The density of zooplankton has generally decreased, but we have seen an increase in rotifera groups (zooplankton), the main indicators of polluted water ecosystems. In contrast, the diversity and density of macroinvertebrates increased after treatment. The device used in the context of our study is a purely lentic environment. The resumption of trials in the lotic environment and the increase of the duration of the experiment prove to be indispensable in order to evaluate the impact of this technique on the two ecosystems different from each other by the water stability.

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