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RESEARCH ARTICLE

INFLUENCE OF STOCKS OF NITROGEN AND PHOSPHORUS ON DISTRIBUTION OF WATER HYACINTH *(Eichhornia crassipes*) IN LAKE NOKOUE IN BENIN.

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Abstract

The present study aimed to evaluate the influence of nitrogen and phosphorus stocks on the distribution of water hyacinth in Lake Nokoue. Apart from conventional water quality parameters, the range of concentrations (in mg /L) of the parameters indicative of nitrogenous pollution and phosphorus and dissolved oxygen measured in the lake is as follow: NO_2^- (0.01 to 74); NO_3^- (1.00 to 24.94); NH_4^+ (0.02 to 8.80); PO_4^{3-} (0.04 to 7.65); P_{total} (0.0 to 1.2); O_2dissolved (2.10 to 4.25). The concentrations of nutrients are in most of the cases above the WHO and Benin standards related to surface water quality. Such high concentrations justify the invasion of the lake by the water hyacinth (*Eichhornia Crassipes*) when salinity levels are low (< 3 ‰) in these water.

INTRODUCTION

Surface water bodies naturally receive different organic and inorganic inputs. It concentrates not only natural nutrients but also, some nutrients due to anthropic activities. All these cause eutrophication, which is manifested by excessive development of vegetation in water bodies. This can lead to anoxic conditions, followed sometimes by production of some toxics substances (Oraison and al., 2011). Among elements which favor these developments, phosphorus and nitrogen are very important. They are prone to be limiting factor in natural condition under 5µg/L for phosphorus and 50µg/L for nitrogen (Rosemonde and al., 1993; Souchon and al., 1996).

Nitrogen is a mineral element, which, with carbon, oxygen and hydrogen is one of the principal components of living species, ecosystems and agro systems. It is naturally fixed by vegetation, particularly by leguminous plants.

Water hyacinth (*Eichlornia crassipes*), introduced firstly in Africa (Egypt and South Africa) at the end of the years 1800 (Center, 2002), appears today as one of the aquatics vegetations, invading, the most worrying, principally in Africa where it invades streams, rivers, natural and artificial lakes (Hill and Cetzee, 2008). Its growth is usually rhythmed by seasonal variations and different environmental factors (Hadj and al., 2008).

Lake Nokoue, which is the subject of this study, is almost permanently, colonized by floating plants and particularly, water hyacinth. Aoyami and Nishian (1994) showed that this plant grows well when the water lodging it, is rich in nutritive salt, specially nitrogen and phosphorus, which this plant extracts thanks to its well developed root system. It's also important to know that, when the salinity degree becomes higher (> 3mg/L) (Soclo, 2000), these plants die and degrade, causing the water body to be less transparent, unclear.

This work aimed at evaluating the influence of nutritious salt load, especially, nitrogenous and phosphorous, on the distribution of water hyacinth in lake Nokoue, in order to identify some pollutant sources of the interested lake.

I. Methods and materials

1. Localization of the lake

Lake Nokoue is located between parallels 6°20’ and 6°30 North and the meridians 2°20’ and 2°35’ East (Sagbohan, 2003). With a surface of 150 km², it communicates in the north with So delta’s river and Oueme river and in the south with the sea by Cotonou’s stream. It receives waste water and rain water drained by rehabilitation infrastructures built in Cotonou and Abomey-calavi cities. Besides, it has some lacustrine villages as Ganvie and So-Tchanhoue and serves as receptacles for latrines on piles which are raised in; this explains the exacerbation of peril fecal and the organic pollution observed.

2. Sampling collection

Samples have been collected at seven different stations mentioned on the following figure:

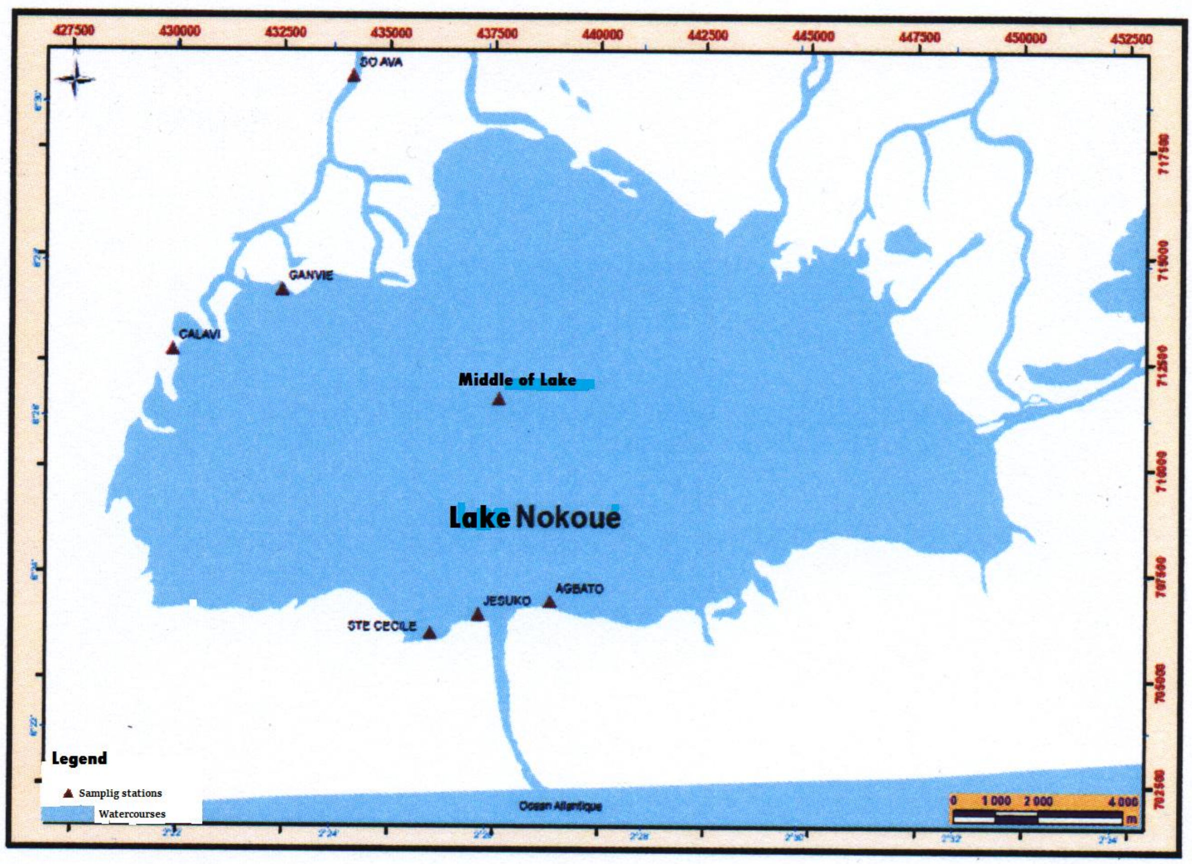

Figure 1: Sampling stations

Totally, six campaigns were organized. All the samples were taken 50 cm under water surface, between 7 am and 11 am, in glasses bottles initially washed and rinsed with the water to be sampled. These bottles was completely filled without air bubble, tightly closed and packed in an aluminum paper to protect them from sunray. In addition, 250mL of water were sampled by the means of a container for in-situ measurements. The container was rinsed 3 times with the water to be sampled before proper water sampling for in-situ measurements. Water samples were afterwards conserved at a temperature of 4°C and they were analyzed in the laboratory within 48 hours after the sampling.

3. Analysis methods

For samples, temperature, conductivity, pH have been measured in situ by a saline conductivimeter measuring many parameters, standard ProLine LF 197/LF 197-S, while dissolved oxygen has also been measured in situ with a kit of

Winkler (Rodier, 1984). Suspended matters are known using the drying gravimetric method. Ions contents were obtained thanks to the following methods:

- nitrate (NO_3^-) contents were obtained by the method of salicylate of sodium;
- nitrite (NO_2^-)contents were obtained by the method of Zambelli's reactive;
- ammonium (NH_4^+) contents were obtained by the method of Nessler;
- phosphate ($H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}) contents were obtained by the method of Nessler;
- total phosphorus contents were obtained after mineralization in acid midpoint (Rodier, 1984).

The depth determination is done by a Sechi disc. Its value is noted when the disc introduced in water becomes non-perceptible.

II. Results and discussion

1. Water temperature

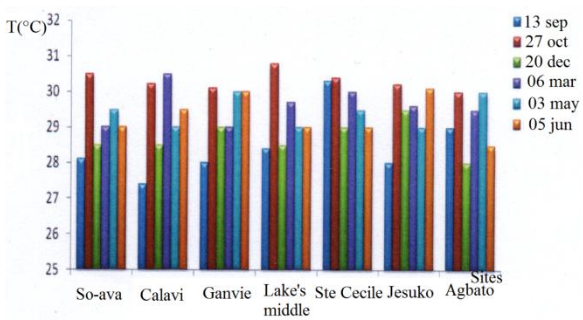

Figure 2: Spatio-temporal variation temperature in the lake Nokoue's waters

Temperature changes from 27.4°C in september at Calavi to 30.8°C on the lake middle in october with an average of 29°C during this work time. Based on previous works from by Mama (2010), the optimum temperature for water hyacinth growth is 30°C. Noted values are so in favour to water hyacinth proliferation in lake Nokoue.

2. Water pH

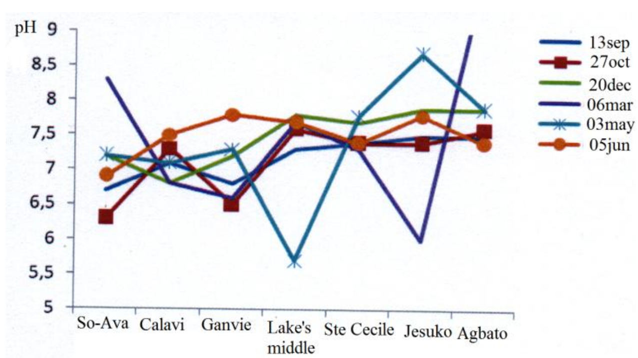

Figure 3: Spatio-temporal variation of pH in lake Nokoue's waters

Figure 3 shows:

- an evolution of pH, located between 5.72 (in mars) and 8.70 (in october), at Jesuko with an average of 7.3 compatible to those of majority surfaces water;
- pH values inferior to 6 at some locations (middle of lake in may and Jesuko in march). As this values characterize polluted spaces by minerals and/or organics acid, we can then conclude that these locations receive acid pollutants, generated by anthropic intensive activities. From Wilson and al. (2005), nutrients, principally nitrogen and phosphorus are considered as indicators of tropical level capable to favor macrophyte and mostly water hyacinth apparition.

3. Dissolved oxygen contents in water

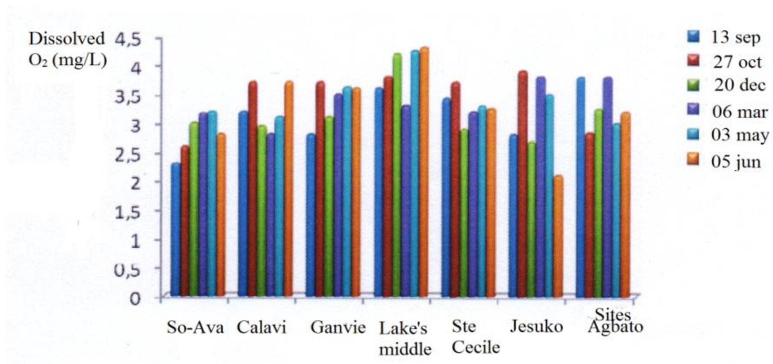

Figure 4: Spatio-temporal variation of dissolved oxygen contents in lake Nokoué's waters

Figure 4 shows that dissolved oxygen changes from 2.1 mg/L at Jesuko to 4.5 mg/L in the middle lake in June with an average of 3.3 mg/L. These low rates characterize environments with insufficient oxygen and where aquatic life is consequently in danger. This oxygen shortage is possibly due to the presence of heavy organic load in the lake or due to disposal of domestic and vegetal waste, especially dead water hyacinth which degrade at bottom of the lake.

4. Variation of electric conductivities in lake's waters

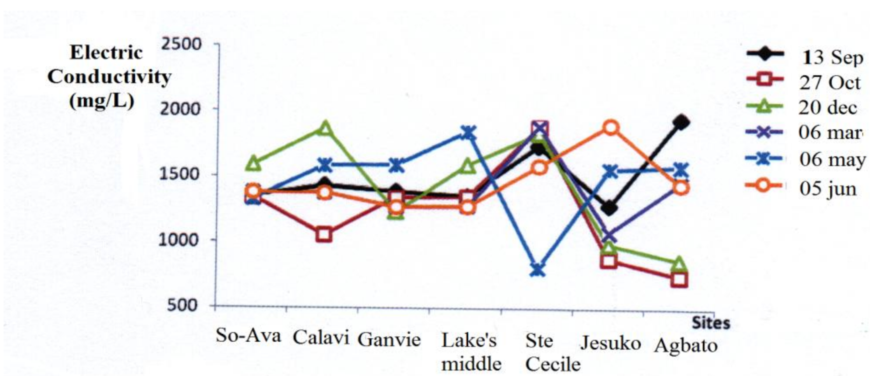

Figure 5: Spatio-temporal variation of the lake's waters electric conductivity

Electric conductivities values range from 749µS/cm in October and 1953 µS/cm in September (at Agbato) with an average of 1435 µS/cm. These relatively high values cause to suspect a brackish water intrusion into the lake. The higher conductivities values at Jesuko and Ste Cecile stations, compared to the average and to those observed at the others stations, indicate a high mineralization with organic matters or important ionic charges coming from domestic wastes disposal drained to the stations by streams, dishes and other drainage systems.

5. Salinity of lake's waters

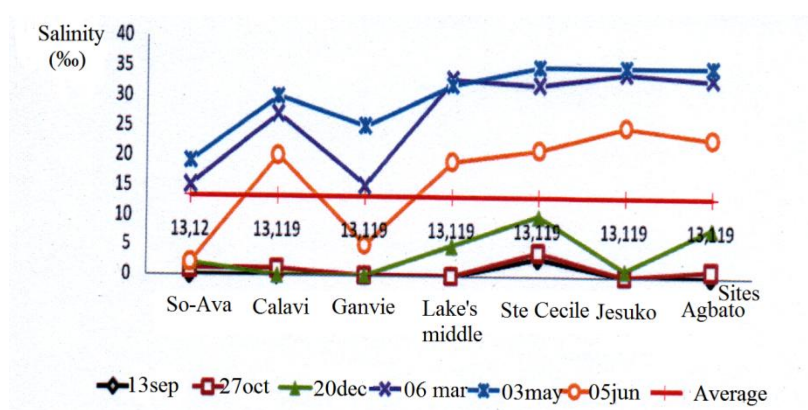

Figure 6: Spatio-temporal variation of the lake's waters salinity

For all the stations, salinity changes from 0 to 35 ‰. Values near 35‰ noted at Agbato, Jésuko and Ste Cecile indicate a marine intrusion into the lake. It is know that salinity has effect on water hyacinth distribution in water bodies. Indeed, values close to zero observed in September, October and December at So-ava, Calavi, Ganvie, in the middle of the lake and Jesuko explain the apparition of the water hyacinth at these stations, because the water hyacinth doesn't support salinity above 3‰ (Soclo, 2000).

6. **Variation of lake's waters depths**

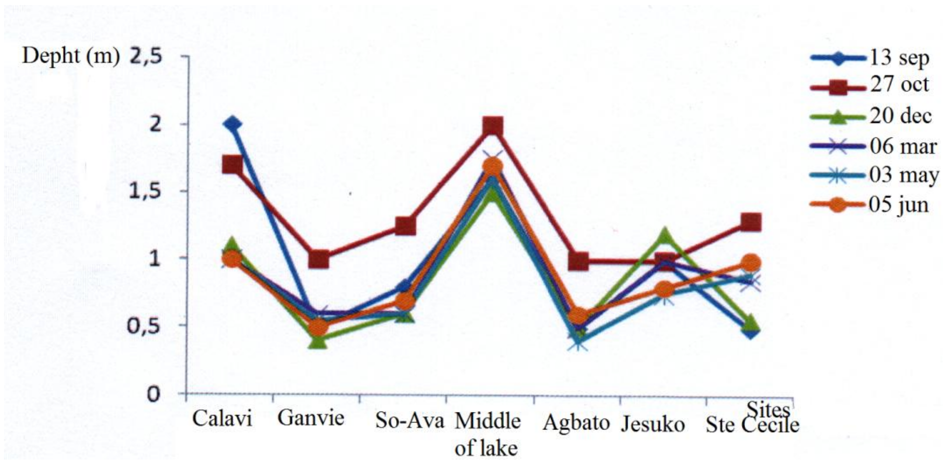

Figure 7: Differents depths of the lake's waters

Previous works in 1980 showed that depths value were inferior to 3 m (De Casabianca and Laugier, 1995) and were as follow: 2.8 m on 28.5 km²; 1 to 2 m on 104 km²; less than 1m on 30 km². A decreasing in order of 0.6 m of the maximum depth has been observed in around 20 years (about 0.03 m / year). The high use of fish's traps (made of vegetal boughs called "*Acadjas*") combined with the sedimentary deposit due to the lake's hydrodynamic are the principal causes of this tendency of the filling up of the lake. Also, eutrophication contributes to this filling up of the lake (Mama, 2010).

Concerning the water's depths, the different values observed during this work range from 0.4 to 2 m with the lower levels at Calavi and Ste Cecile during December and May. At the channel of So's river and at Ganvie where water hyacinth proliferation is favored, water's depths are respectively 1.5 m and 0.7 m during the same seasons. According to Mama (2010), macrophytes decompose in February in the lake and in July, at the beginning of the apparition and of the water hyacinth growth. Considering these observations, it could be difficult to systematically assign the filling up of the lake noted at Ganvie to a stock of water hyacinth waste in the lake's bottom.

7. **Variations of nitrogenous and phosphorated nutrients rates in lake's waters**

In aquatic environment, the increase in organic matter and mainly the increase in nitrogen and in phosphorus are often regarded as responsible of phenomenon related to aquatic plants proliferation. Phosphorus is usually considered as limiting factor in freshwater (Smith and al. 1999). However, the role of nitrogen should not be under-valued.

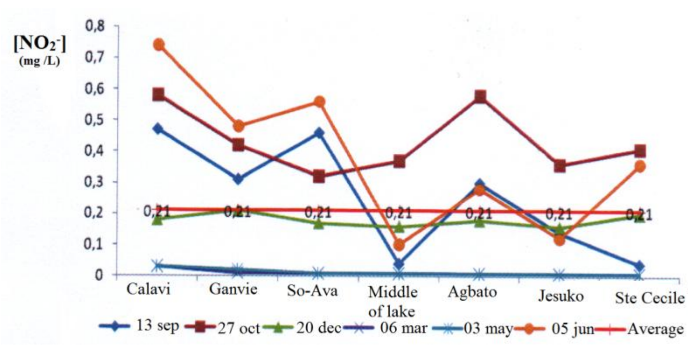

Figure 8: Spatio-temporal variation of nitrite contents in lake Nokoue's waters

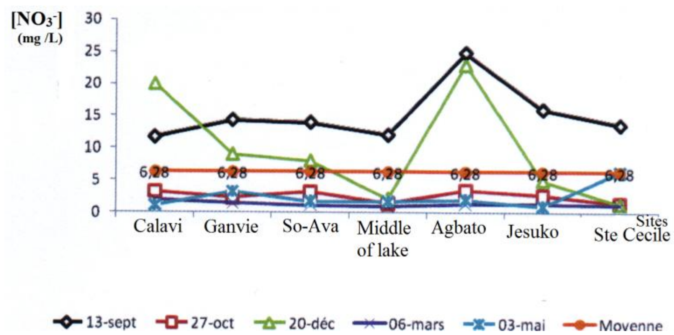

Figure 9: Spatio-temporal variation of nitrate contents in Nokoue's lake

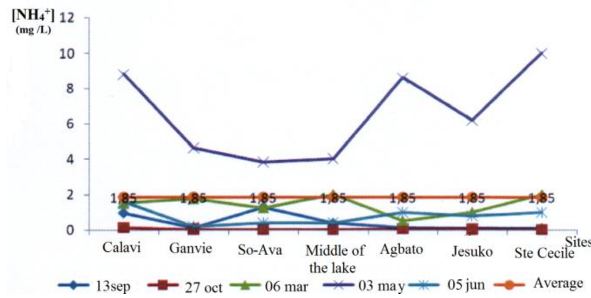

Figure 10 : Spatio-temporal variation of ammonium contents in Nokoue's lake

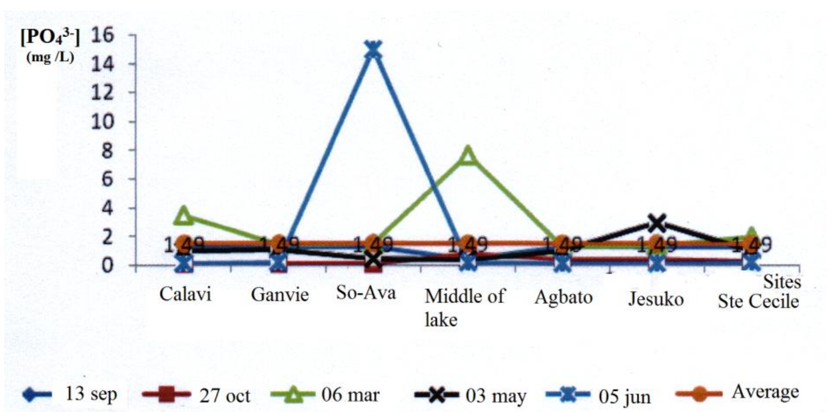

Figure 11 : Spatio-temporal variation of phosphate contents in Nokoue's lake

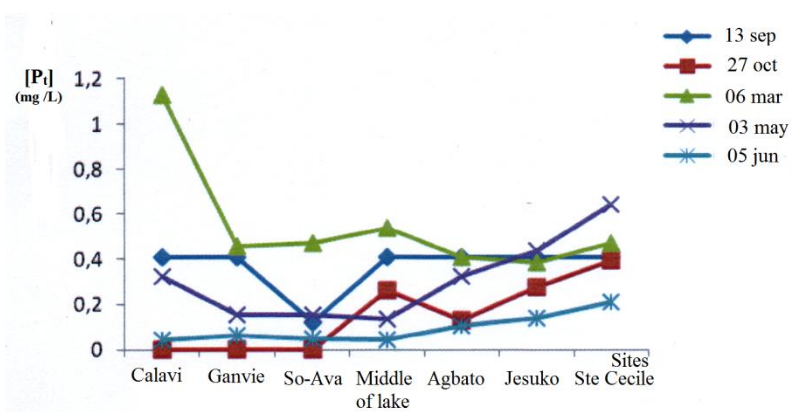

Figure 12 : Spatio-temporal variation of total phosphorus rate in lake Nokoue's waters

Analysis of figures 9, 10, 11 and 12 shows that:

- nitrites, as it is observed in most of surface water, are in low quantity than other nitrogenous salts. Their average concentration is 0.21mg/L. Higher values are obtained in March and May while lower values are obtained in October and June. These values are in part, in relation with those obtained in lake Nokoue's waters by Dovonou, (2011);

- nitrates represent nutritive salts mostly abundant in September and October, where peak concentrations are respectively 25 and 20 mg/L; the minimum for this salt is 0.9mg/L obtained in March. This high rate of nitrate, obtained mostly in September, which coincides with the end of the rain season in the North, can be explained by important supply of this salt by waters running from the north region of the country, which wash on their ways many farms. Obtained values are still superior to those obtained by Mama (2010) for the same lake waters;
- higher concentrations of ammonium ion are observed in May with a maximum of 8.8mg/L. The minimum for this ion (0.07mg/L) is obtained in September. These high concentrations of ammonium ion could result from the nitrates reduction due to development of anaerobic conditions in the lake; these concentrations are however considerably superior to those obtained by Dovonou (2011);
- higher concentrations in phosphates had also been observed in May with a maximum value equal to 7.65mg/L. The minimum and average values noted in the lake are respectively 0.04mg/L and 1.31mg/L;
- content in total phosphorus range from 0 to 1.2 mg/L. The higher values are obtained at Abomey-Calavi all the seasons and at Ste Cecile in May.

All these high concentrations indicate that the presence of phosphorus in the Nokoue lake could be attributed to many sources. The sources are mainly incoming water from the northern, probably charged with agricultural phosphorous nutrients; domestics waste disposals and stream coming from waterside localities.

III. Distribution of water hyacinth and nutritive salts rates

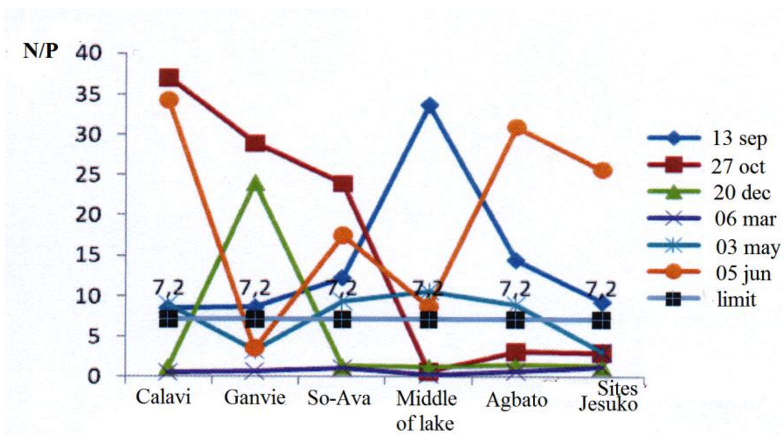

Figure 13 :Variation of the relation N/P in the lake's waters according to the seasons and the stations

Figure 13 shows that the ration N/P (Nitrogen / Phosphorus) values obtained range from 0.28 (in the middle of lake, in March) and 38.1 (at Calavi in October).

The process frequently used to know which element between nitrogen and phosphorus do limit algal biomass development consists of comparing value of N/P measured in water with those measured in a non-deficient algal population. A ratio of N/P greater than 7.2 testifies a limitation by phosphorus and a ratio of N/P less than 7.2 indicates a limitation by nitrogen (Barroin, 2004).

Considering those criteria, the study area is balanced during nearly all seasons. However, in September, all the stations show a ratio of N/P greater than 7.2; in June and May this ratio is also superior to 7.2 everywhere except Ganvie. Finally in October, the ratio is greater to 7.2 only at Ganvie, Calavi and So-Ava. So, in this period, phosphorus becomes a limiting factor for the development of aquatic plants. Meanwhile, this element is the most eutrophicant factor in water bodies. This explains the reason why water hyacinth population is either inexistent or very little present where phosphorous is found, though salinity conditions are favorable to their development.

During other seasons, except in December at Ganvie, the ratio N/P is very inferior to 7.2 at nearly all the six stations. Nitrogen, being the limiting factor in these conditions for the development of aquatic plants, particularly water hyacinth, water bodies are then colonized because the salinity conditions are also favorable.

Conclusion

This study enables to appreciate the water hyacinth distribution at the Nokoue lake surface as a function of the nutritive salt contents. Indeed, quantitative and qualitative data obtained show a positive correlation between the

plants distribution and the contents related to nitrogenous and phosphorous salts represented by the ratio N/P. The aquatic vegetation is integrally included in the natural complex balance of the lake. A fast proliferation of this plant is a threat to any ecosystem because it provokes insufficient oxygen in the environment, loss of biological diversity and of economic capacity and a long term filling up of the lake.
Finally, this study in relation with those did in the same environment, show that water hyacinth proliferation and distribution are conditioned not only by water body salinity (salinity ≤ 3‰) but also by N/P ratio.

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