Nutrient Distribution in a Fish Pond at Rwasave Fish Farming and Research Station, Rwanda

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Abstract

This paper reports on the study nutrient distribution in the fish pond carried out at Rwasave at Fish Farming and Research Station in Butare, Rwanda. The purpose of the study was to determine the nutrient distribution in a single fishpond supplied by Rwabuye River and fertilized by rabbit dung. Vertical and horizontal distribution of nutrients in the fishpond were assessed and the nutrient concentrations in the inflow and outflow of water from the fishpond were determined. Twelve parameters were monitored. Temperature, pH, Dissolved Oxygen, Electrical Conductivity, Turbidity and Transparency were measured directly in the field. Total Nitrogen, Total Phosphorus, Nitrate-Nitrogen, Nitrite-Nitrogen, Ammonium-Nitrogen and Orthophosphate were measured in the laboratory using different standard analytical methods. Eight sampling sites were located within the pond, in addition to inflow and outflows. The sampling was done fortnightly. The water samples were collected at the surface and bottom of the pond. Samples were taken using a Van Dorn Bottle water sampler and were preserved and stored in cooler boxes, and later analyzed for nutrients using colorimetric methods. Samples from sediments were taken using a metallic stick and fish using a fibre mesh. Both sediments and fish samples were analyzed for TN and TP content.

Statistically, the results indicate that the nutrient concentrations in the pond were higher than those in the inflow. This is due to the accumulation of nutrients and additions due to rabbit droppings. The TN averaged 25.43±5.82 mg.l^{-1} and TP 1.25±0.95 mg.l^{-1} in the pond, in inflow TN was 25.1±9.1 mg.l^{-1} and TP 0.82±0.79 mg.l^{-1}. The average concentration of TN in fish for the two times of sampling was 8.75% N and 8,827 ppm for TP. In sediment the mean concentrations were 0.2%N and 236.5ppm respectively for TN and TP. The mean Secchi disk measurement was 26 cm and indicates that water pond was turbid. The nitrate concentrations show that the pond was exposed to eutrophication. Previously reported figures also are generally low compared to the results of this study and urgent control is therefore required. It was observed that there is generally a high level of nutrients in the Rwasave fishpond. It is recommended that proper nutrient control practices be adopted for avoiding excess nutrients and environmental pollution.

Key words: *Nutrient distribution, Fish farming, Fishpond, Rwabuye, Rwasave, Rwanda.*

1. Introduction

Pressures on natural resources have become intense due to the rapid increase in population and continuing increase in the standards of living (Kapetsky, 1994). In many situations where food security is precarious, women and children are the most vulnerable. The target of the World Food summit in 1996 was to reduce the undernourished population from 792 million to 400 million by 2030. For this to be achieved, more effort should be directed at low-cost and sustainable production systems. Fish is nutritionally important and provides 20% or more of animal proteins to the majority of the population in sub-Sahara Africa (Kipkemboi, 2006). Earlier studies by Kapetsky (1994) indicated that there is a high biophysical potential for aquaculture on the continent. Today, in sub-Saharan Africa, one out of every two people (49%) lives on less than $1 a day. While in other regions chronic hunger is receding, in sub-Saharan Africa malnutrition is still rising in both absolute and relative terms. More than one third (34%) of the sub-Saharan African population is undernourished. Between 15,000 and 20,000 African women die each year (41–55 every day) due to severe iron-deficiency anemia. Vitamin A deficiency in children is common across the whole continent, and food insecurity remains one of the most visible dimensions of poverty and is generally the first sign of extreme destitution (Béné and Heck, 2005).

Rwanda is a country characterized by subsistence agriculture and prevalence of nutritional deficiencies. For example, across the country 37% of the total population consumes fewer calories than the minimum requirement, and 64% of the population is deficient in protein intake (Engle, 1993). In Rwanda fishing is conducted by cooperatives and associations; mainly in the lakes Cyohoha, Kivu, and Mugesera. Owing to inadequate restocking of fish in the lakes, however, the output is quite low (RDG, 2005). Current efforts to develop the fishery industry include encouraging and supporting fish farming by means of rehabilitating the old, and opening up new fish ponds (RDG, 2005). With the increasing demand for fish as a source of food, the management techniques in systems with high densities of fish and high feeding rates has been of great concern in making intensive and semi-intensive fish farming viable. The need for reasonably high production rates, requiring reasonably quantities of food and nutrients to be added to the environment, and the cultivation of small animals in high densities could rapidly deteriorate water quality if improperly managed (Pereira, 2001). Nitrogen and Phosphorus are important nutrients in the environmental systems as they are required for the growth and reproduction of organisms. The interruption in the circulation of these two elements could result in water eutrophication and could disrupt aquatic ecosystems functions. The presence of ammonia in water is an indicator of direct pollution. The increase presence of phosphorus and nitrogen in the fish pond may be as a result of the feeds type including dump from animal waste.

In Rwanda fish farming is practice in different places. One of the major fish farming and research station was established at Rwasave in 1982 by the National University of Rwanda and currently produces fish for research and commercial purposes. The station uses different kinds of nutrients to fertilize the ponds. Some nutrients are brought by Rwabuye River and others come from rabbits droppings, pigs and chickens manure. The manure is used to fertilize fish ponds hence to produce plankton to feed fish naturally. Studies on fish farming and nutrient control have been well-reported (Kanangire, 2000). However, it is obvious that when the proper control of nutrients is not applied, there is a potential risk for contaminating the environment. The fish farming station has a laboratory for water and sediment quality as well as food nutrients analysis, however, there is no published information about change in water quality of fish ponds and their impacts on the neighboring environment in Rwanda. At the Rwasave Fish Farming and Research Station the water from the fishponds are routed directly to the Rwasave river except for some experimental ponds where, from fish ponds water is poured into rice plots and from the rice plots to the Rwasave river. This necessitates carrying out this study in order to understand the nutrients distribution in the pond and beyond to get better understanding of how to plan the nutrient flow control in order to avoid excess nutrient discharges from the ponds which could lead to eutrophication and groundwater contamination particularly by nitrates.

2. Materials and methods

2.1 Description of the study area

Rwasave fish farming and research station is located in the Ngoma Sector approximately 3 km from the National University of Rwanda. (Fig. 1). It is approximately 2 km from Butare town, Rwanda's second largest city, and about 130 km south of the capital city of Kigali. On the station the latitude is 02^0 36'09. 5''S, longitude is 29° 45'25. 2''E and the elevation is about 1,625 m above mean sea level. Water used in the ponds is drawn from the Rwabuye River. The supply canal runs 2.5 km from a small dam in the river to the station. The canal passes through some cultivated marshlands where there are some exchanges with standing water. The types of fish produced at the station are *Tilapia Nilotica* and *Clarias gariepinus* (Kanangire, 2000).

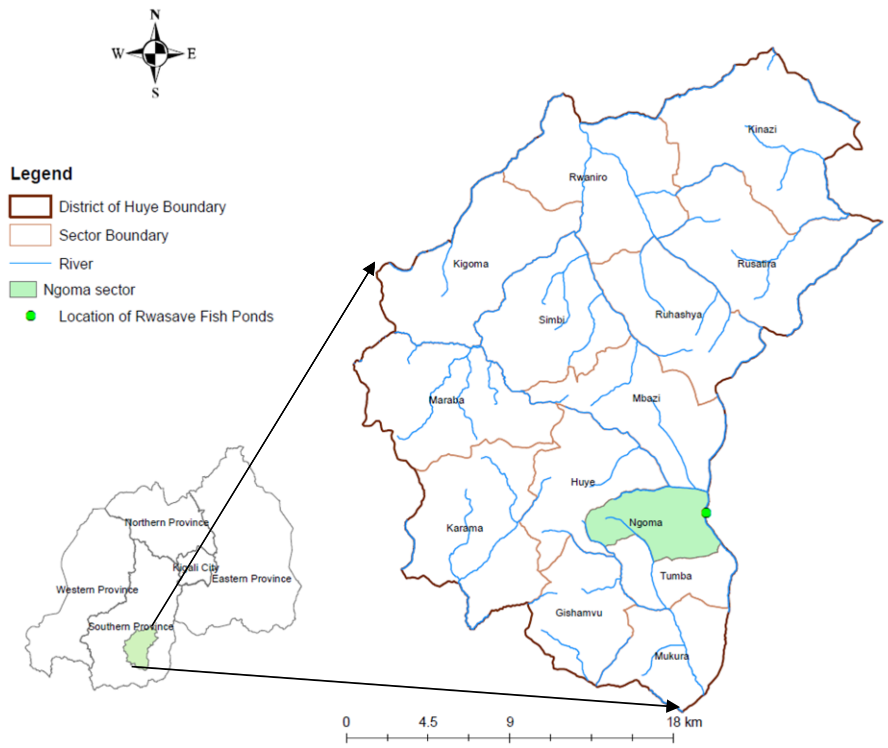

Figure 1. Location of Rwasave Fish Farming and Research Station in relation to Rwanda and the Ngoma Sector

2.2. Location of sampling points in the fishpond

The studied fishpond is in the P series and is called P1 with dimension as shown in the schematic diagram in Fig. 2 and a mean depth is 0.64 m. The assessment of nutrients was done on the influent containing water from the Rwabuye River, pond water at eight sites (surface and bottom each site), nutrients absorbed in sediments, nutrients absorbed by fish and outflow for nutrients which go out from the fishpond for feeding the rice plot. The assessment of horizontal and vertical distribution of nutrients in the pond was done using the aquatic method considering the spatial distribution between points and surface towards bottom for each point. The aquatic method used is shown on Fig. 2.

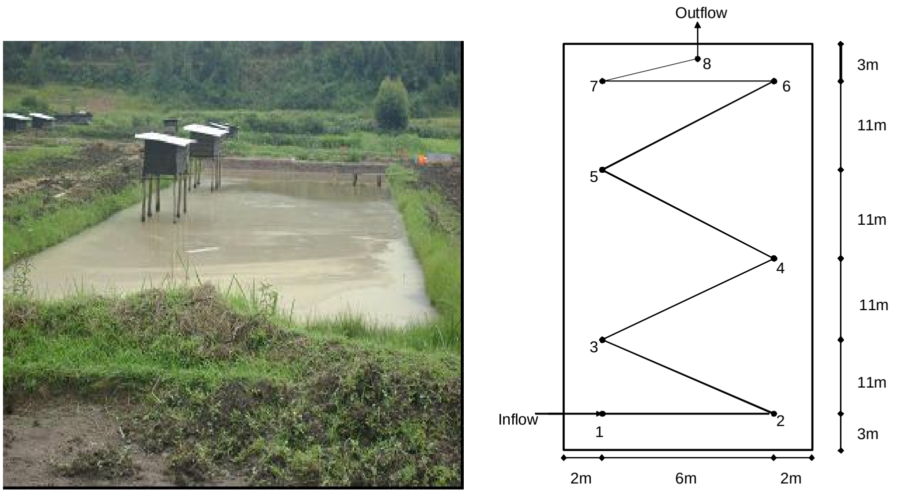

Figure 2. Photo of the studied pond and a schematic on the location of sampling points

2.3 Sampling sites and sampling frequency

The study was conducted from March to June 2009. The first sampling was done on 4^{th} March, 2009 at all sampling sites: inflow, eight points inside the fishpond and outflow. Samples were collected approximately every week and the last water sample was collected on 15^{th} May, 2009. Samples from sediments and fish were also collected two times. The first sampling for sediment was done on 18^{th} March, 2009 while the second was done on 19^{th} May, 2009. The fish samples were taken on 18^{th} March, 2009 and 2^{nd} June, 2009. In total 6 physico-chemical parameters: temperature, pH, Dissolved Oxygen (DO), Electric conductivity, turbidity, transparency and 6 nutrients: NH_4-N, NO_3-N, NO_2-N, PO_4-P,TN and TP.

2.4 Sample collection and analysis

2.4.1 Sample collection

Plastic bottles were used to collect samples of water. Bottles were washed with phosphorus-free detergents and rinsed with 1M HCl for 24 hours before sample collection. They were again rinsed twice with sample water before final sample collection. Fishpond samples were taken at required depths using a Van Dorn sampling bottle. This bottle helps in taking samples at a precise depth. The plastic bottles were labeled according to the site number before sample collection to avoid confusion of samples. The collected samples were preserved as necessary and stored in 560 ml plastic bottles and were placed on ice in cooler boxes before analysis or storage in the laboratory. Temperature, DO, Conductivity and Turbidity were directly measured in the field using HACH field kits. The transparency was measured using a Secchi disk. Sediments were collected using a metallic stick at each point and fish has been collected using the fibre nets.

2.4.2 Sample analysis

Ammonium-Nitrogen (NH_4-N), Nitrate-Nitrogen (NO_3-N), Nitrite Nitrogen (NO_2-N), and Orthophosphate (PO_4-P) were analyzed from filtered water samples using the colorimetric method (Colorimeter HACH (DR/890)). For TN and TP analysis, samples of well-mixed unfiltered water were digested in a pressure cooker for 2 hours at 121^oC with potassium per sulfate ($K_2S_2O_8$) and NaOH to convert all phosphorus to orthophosphate and all nitrogen to nitrates. After digestion, the colorimetric method was used to determine the TN and TP concentrations using colorimeter HACH (DR/890). For TN and TP analyzed in sediment and fish the Kjeldhal method was used for TN and the Ascorbic Acid method for TP after drying all samples at the ambient temperature. Features of data in this study were analyzed statistically based on the mean, standard deviation and the correlation between parameters considering pond surface and bottom using Microsoft Excel Software.

3. Results

The results presented below are based on n = 9, sampling frequency of once per week and standard deviation.

3.1 Characteristics of physical parameters in the fishpond

3.1.1 Temperature

The surface water showed higher temperatures compared to the bottom water.

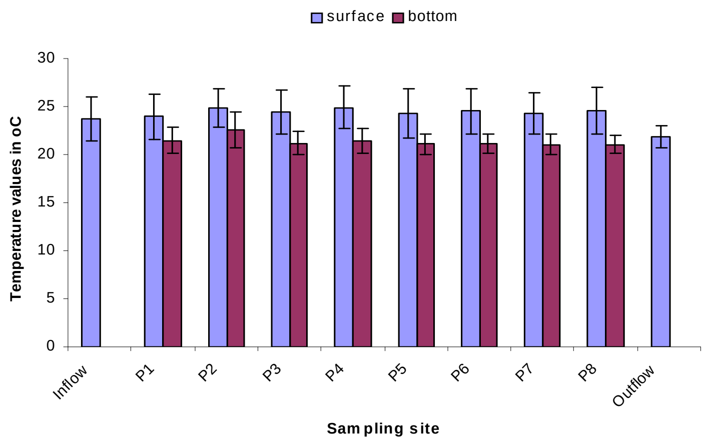

Figure 3. Mean temperature variations at different sampling sites in the Rwasave Fishpond for the period March to May 2009

3.1.2 pH
The general over view shows that pH at the surface seems to be higher than what found at the bottom.

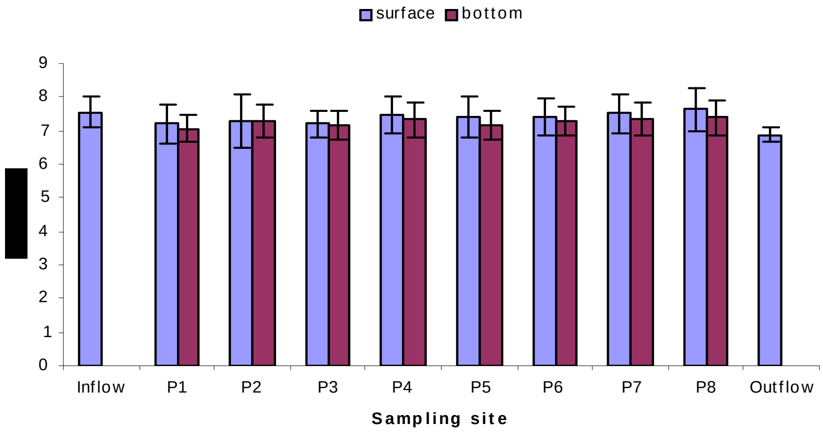

Figure 4. Mean pH variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.1.3 Dissolved Oxygen
The level of DO dropped from the surface to the bottom.

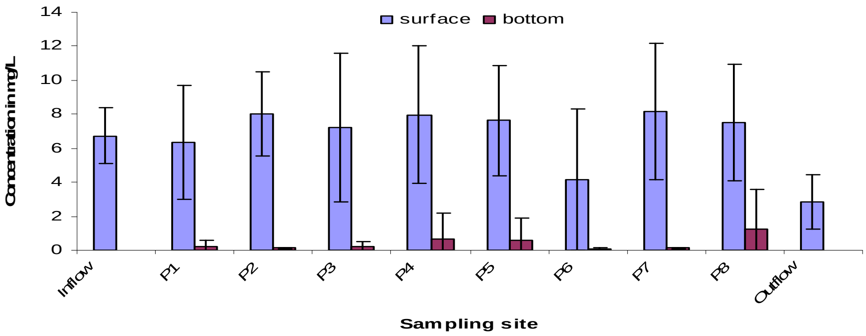

Figure 5. Mean DO variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.1.4 Electrical Conductivity
It was observed that the EC in inflow was lower than the EC at the outflow and the bottom presented the highest EC compared to the surface.

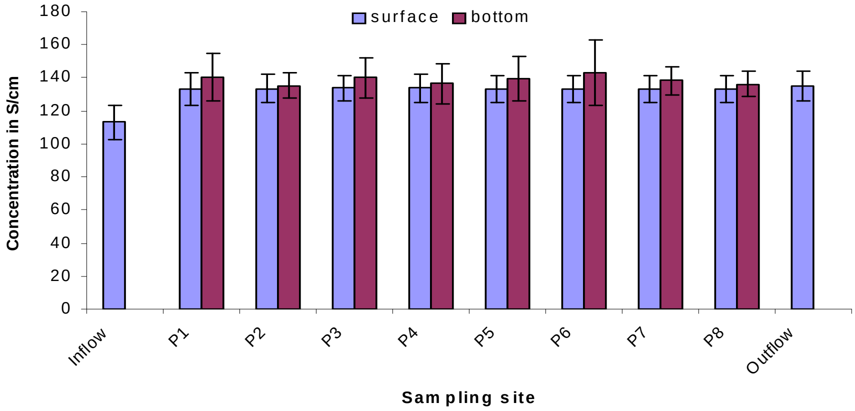

Figure 6. Mean Electrical Conductivity variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.1.5 Turbidity

In general the figure shows that water pond was turbid at the inflow and at the bottom.

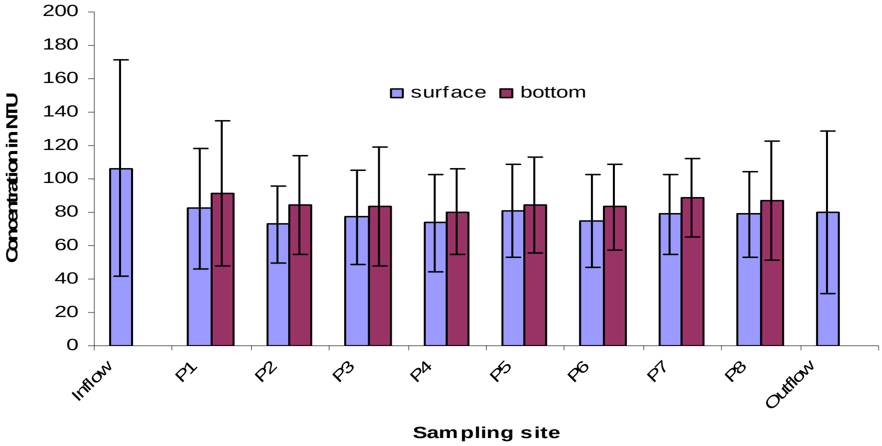

Figure 7. Mean Turbidity variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.1.6 Transparency

The transparency (Secchi disk measurements) variations for the different sampling sites was shown by the figure below:

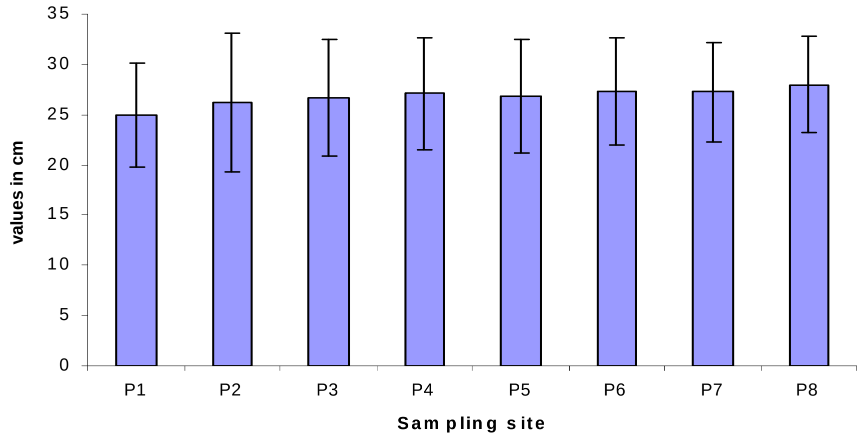

Figure 8. Mean Transparency variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.2 Nutrients profiles and their distribution in the fishpond

3.2.1 Ammonium - Nitrogen (NH_4-N)

In general, it was observed that the level of NH_4-N was increasing from the surface to the bottom.

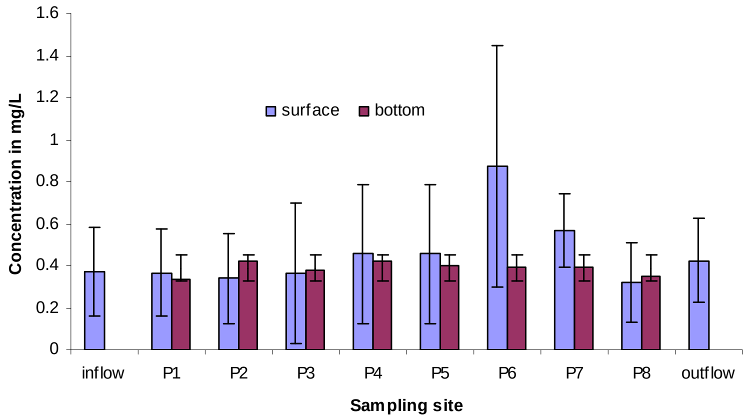

Figure. 9. Mean Ammonium-Nitrogen variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.2.2 Nitrite-Nitrogen (NO_2-N)

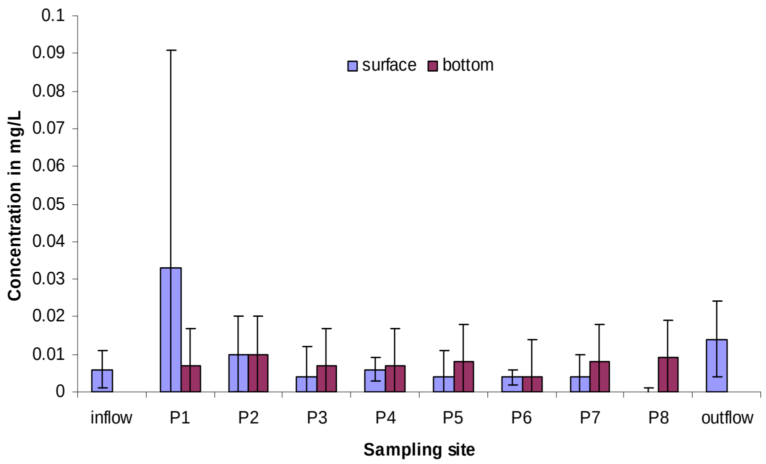

Figure 10. Mean Nitrite variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.2.3 Nitrate-Nitrogen (NO_3-N)

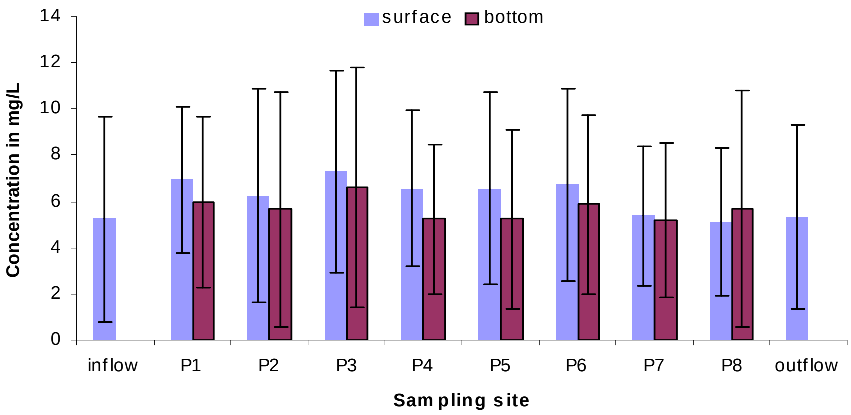

Figure 11. Mean Nitrate variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.2.4 *Total Nitrogen (TN)*

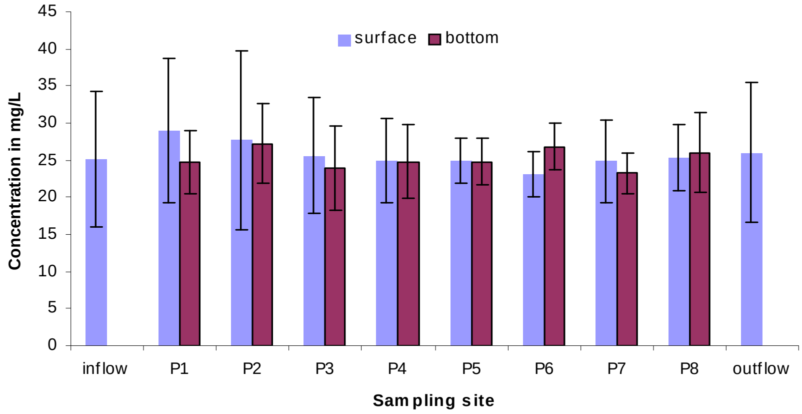

Figure 12. Mean TN variations at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.2.5 *Phosphate (PO_4)*

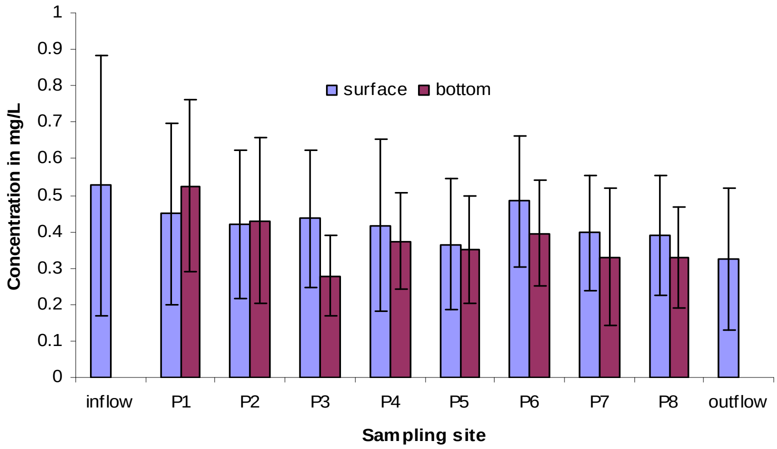

Figure 13. Mean Phosphate variation at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.2.6 Total Phosphorus TP

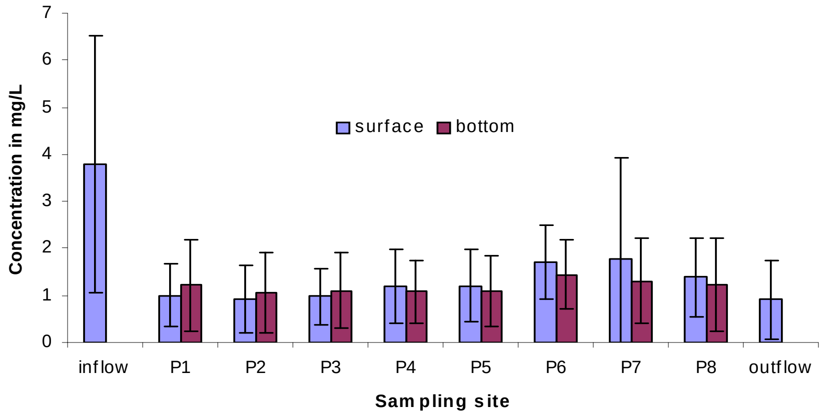

Figure 14. Mean TP variation at different sampling sites in Rwasave Fishpond for the period March to May 2009

3.3 Nutrients distribution in sediment and fish

Table 1. Sediment and Fish analysis results (First and second sampling)

Site	TN (%N)		TP (ppm)	
	18/3/2009	2/6/2009	18/3/2009	2/6/2009
P1	0.2	0.16	2.1875	489.99
P2	0.26	0.07	84.375	306.63
P3	0.3	0.13	15.625	436.66
P4	0.36	0.08	3.125	333.33
P5	0.28	0.1	6.25	339.99
P6	0.28	0.1	2.5	313.33
P7	0.26	0.25	10.3125	726.65
P8	0.28	0.12	212.5	499.99
Mean	0.28	0.13	42.11	430.82
StDev	0.04	0.06	74.16	142.84
T-test	0.0017		0.0002	

Table 2. Concentration of TN and TP in fish sample

Fish	TN (%)	TP (ppm)	Fish	TN (%)	TP (ppm)
18/3/2009	12.1	5125	2/6/2009	5.47	12530

3.4 Rabbit contribution to the fishpond feed

Experiment was done three days according to intervals between hours.
The average in three days was: 652 $ml.day^{-1}$for waste liquids (urine) and 256.11gr $day^{-1}$for waste solids (dropings). Nutrients from these wastes were:
TN = 1.7 $mg.l^{-1}$ TP = 0.47 ppm in dropings
TN = 21.73$mg.l^{-1}$ TP =11.55$mg.l^{-1}$ in urine.

3.5 Summary of parameter levels in comparison to expected levels in fishponds

Table 3. Comparative analysis of fishpond water quality parameters against recommended levels

		Measured value			
		maximun	*Minimum*	*Mean and stdev*	*Recommended values in fishpond*
Temperature	^oC	28	19.6	22.93 ± 1.77	42 - 14 Tilapia and 25 - 21.5 Clarias
Temperature	^oC	28	19.9	22.93±1.77	42-14 Tilapia and
pH		8.6	5.8	7.32 ± 0.53	9.0- 6.5
DO	$mg.L^{-1}$	16.01	0	4.03 ± 2.20	5
Conductivity	µS/cm	193.4	122	136.01 ± 10	200 - 100
Turbidity	NTU	187	34	81.34 ± 29.36	60- 30
NH_4-N	$mg.L^{-1}$	3.54	0.06	0.43 ± 0.33	0-2
NO_2-N	$mg.L^{-1}$	0.1	0	0.01 ±0.01	4
NO_3-N	$mg.L^{-1}$	19.4	1.2	5.93 ± 3.96	0.05- 0.005
TN	$mg.L^{-1}$	58	11	25.43 ± 5.82	
PO_4-P	$mg.L^{-1}$	0.94	0.07	0.4 ± 0.18	0.005-0.5
TP	$mg.L^{-1}$	7.32	0.27	1.25 ± 0.95	

3.6 Variation between surface and bottom for each parameter

Table 4. T-test results for the comparison between surface and bottom water quality

Sampling run	Sampling Points																Average	StDev
	P1		**P2**		**P3**		**P4**		**P5**		**P6**		**P7**		**P8**			
	S	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**		
TP	0.00		0.29		0.50		0.49		0.73		0.69		0.53		0.55		1.25	0.95
Ortho-P	0.44		0.75		0.07		0.50		0.84		0.25		0.31		0.45		0.40	0.18
NH_4-N	0.42		0.16		0.78		0.50		0.36		0.22		0.51		0.43		0.43	0.34
NO_3-N	0.36		0.25		0.32		0.18		0.11		0.11		0.80		0.54		5.93	3.96
NO_2-N	0.45		0.18		0.61		0.80		0.42		0.89		0.40		0.19		0.01	0.01
TN	0.28		0.92		0.55		0.93		0.91		0.31		0.51		0.76		25.43	5.82
T°	0.00		0.01		0.00		0.00		0.00		0.00		0.00		0.00		22.93	1.77
pH	0.22		1.00		0.52		0.22		0.04		0.36		0.25		0.12		7.32	0.53
DO	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		4.03	2.20
EC (uS/cm)	0.07		0.16		0.16		0.16		0.08		0.09		0.07		0.12		136.01	10.13
Turbidity	0.33		0.04		0.29		0.11		0.53		0.01		0.06		0.46		81.34	29.36

4. Discussion

4.1 Characteristics of physical parameters in the fishpond

4.1.1 Temperature

The surface water showed higher temperatures compared to the bottom water (Fig 3). It is important to note that the temperature variation at the surface ranged from 23.9 ±2.3 ^{o}C to 24.9 ±2.2 ^{o}C. The highest value was at P4 whereas the lowest was at P1. The mean temperature in the whole fishpond was 22.9±1.8 ^{o}C. The difference in temperature was likely due to the sunlight rays, with the intensity decreasing from the surface to the bottom. The water temperature in the pond could be different spatially depending on the sampling time for each point in the pond. The difference in temperature between inflow and outflow is mainly due to the fact that the outflow of the fishpond is located at the bottom whereas the inflow is at the surface.

4.1.2 pH

It is notable that the pH was in the acceptable range for the Canadian guidelines for aquatic life which stipulates that pH should be maintained between 6.5 and 9.0 (CCME, 2004). Kipkemboi (2006) reported pH values of 7.47 to 9.06, whilst Nathan and Hugh (2003) reported a mean pH value 7.24 in a fishpond. The difference in pH values observed between surface water and bottom water are in line with temperature trends and may be due to the fact that proton release is temperature dependent. In fact, if the temperature is high, acidic substances release their protons easily and when it is low the ionization is low. This partly explains why the pH in inflow is greater than the pH in outflow, as photosynthetic activities in the pond also affect pH levels.

4.1.3 Dissolved Oxygen

As in previous parameters, the DO in outflow was lower than the inflow. The explanation is that inflow is oxygenated by atmospheric oxygen and by photosynthesis. The significant difference between surface water and bottom is probably due to the consumption of oxygen by fish and microorganisms, and the fact that the surface water is strongly oxygenated by the atmospheric re-aeration and photosynthetic oxygen input. The use of oxygen by microorganisms to decompose the organic matter (from rabbit waste, fish waste, etc) could substantially contribute to the depletion of oxygen with depth. Light penetration is also limited which means algae activity only take place in the upper layers of the pond water. Although the measured DO is within the acceptable range of 5mg.l^{-1} for the fishponds (Ruth, 1992), significant difference in DO for the chosen sampling points were observed in this study.

4.1.4 Electrical Conductivity

In general, the bottom presented the highest EC compared to the surface. The mean EC for the whole fishpond was 136±10 μS/cm. These values were lower than the results obtained in Kusa manured fishpond of 4.62±0.53 mS/cm (Kipkemboi, 2006), but they are in the range acceptable for the fishpond of 100 - 200 μS/cm (Nathan, 2003). A similar study on fishponds was done by Nathan and Hugh (2003) who found 204 μS/cm in the studied fishpond. Average levels of EC of 144 μS/cm were reported at Rwasave fishponds (RukeraTabaro, 2001).

4.1.5 Transparency (Secchi disk measurements)

The values found were lower compared to the acceptable range in fishponds 38 - 50 cm (Anyanwu, 2003). The general observation was that the spatial distribution was almost the same in the pond; the results showed that there was no significant difference between points according to the spatial distribution but it tended to increase in the direction of the water flow.

4.2 Nutrients profiles and their distribution in the fishpond

4.2.1 Ammonium - Nitrogen (NH_4-N)

The results were in accordance with the findings on Kusa manured fishponds by Kipkemboi (2006). He found 0.40±0.06 $mg.l^{-1}$, Nivrfitilov (2006) found a range of 0.00 - 2.23 $mg.l^{-1}$. The mean NH_4-N in this study was 0.43±0.34 $mg.l^{-1}$. The high values at P6 and P7 are related to the input of the rabbit droppings in the pond.

4.2.2 Nitrite-Nitrogen (NO_2-N)

In general, the concentration of nitrite is supposed to be nil in the fishpond. Nathan and Hugh (2003) found 0.001 $mg.l^{-1}$ in their studied fishpond. The high value at P1 denotes nitrification activities as the influent is aerated upon entering the pond.

4.2.3 Nitrate-Nitrogen (NO_3-N)

The findings from RukeraTabaro (2001) were 0.001 $mg.l^{-1}$ and from Nathan and Hugh (2003) were 0.01 $mg.l^{-1}$ NO_3-N. Kipkemboi (2006) found 0.21±0.03$mg.L^{-1}$in Kusa manured fishponds whilst Navrfitilov (2006) found a concentration range 0.000 - 4.29 $mg.l^{-1}$ in the studied fishpond. This shows that Rwasave fishpond contain high concentration of nitrate compared to other findings. The high levels are also consistent with the influent levels which influenced the levels in the whole pond.

4.2.4 Total Nitrogen (TN)

In general, it was observed that the TN levels were decreasing from surface to bottom (although there were some exceptions). These concentrations were higher than findings from Kusa manured fishpond in which the mean TN concentration was 1.25±0.02 $mg.L^{-1}$ (Kipkemboi, 2006) and in Rwasave fishpond RukeraTabaro (2001) found 4.95 mg. $l^{-1.}$ Considering the levels of NH_4-N and NO_3-N, it is observed that most of the nitrogen in the pond should be in the organic form. This means that the practice of feeding the fishponds with organic manure needs to be controlled in order to limit excess nutrient feed.

4.2.5 Phosphate (PO_4)

In this study, mean concentration of phosphate in the studied fishpond was 0.4±0.2 $mg.l^{-}$

The findings from Nathan and Hugh (2003) showed 0.06 $mg.l^{-1}$ PO_4-P and Rukera-Tabaro (2001) found 0.26 $mg.l^{-1}$ PO_4-P. Kipkemboi (2006) found 0.05±0.01 $mg.l^{-1}$in Kusa manured fishponds. Navrfitilov (2006) found 0.00 - 0.12$mg.l^{-1}$ as the range of phosphate in the studied fishpond.

4.2.6 Total Phosphorus TP

The mean concentration of TP in the studied fishpond was 1.2±1.0$mg.l^{-}$1. These results were higher compared to other findings. Kipkemboi (2006) 0.18±0.01$mg.l^{-1}$, Navrfitilov (2006) 0.03-0.21 $mg.l^{-1}$ and Rukera Tabaro (2001) 0.33 $mg.l^{-}$1. Again, these results also showed that phosphorus was mainly in the particulate form, which means there is excess feed of organic manure into the pond (Anywanyu and Nathan, 2003).

4.3 Nutrients distribution in sediment and fish

The assessment of nutrients absorbed in the sedimentation processes was done two times. The results showed the highest concentration of TN on P4 due to the load from leguminous field around the pond since some samples were taken in the rainy season. Therefore the nitrogen content could have reached the sediment in the pond hence the highest value was observed. The amount of TP was almost low in the entire water pond probably because of fish uptake as it was observed that there was a high concentration in the fish. However, the highest concentration found at P8 is attributed to the load from waste compost deposed nearest P8 during the sampling time. The highest concentration at P2 also should be coming from the leguminous field loading into the pond.

Results for the first and the second sampling are presented in Table 1 for TN and TP respectively. The spatial distribution profile inside the pond was almost the same for the two sampling runs although the second sampling presented highest concentrations for TP on P7. This may have been caused by the accumulation as the time goes on. The decrease in TN observed might be due to the various phenomena that involved the nitrogen reactions in the anoxic conditions such as denitrification.

For the two sampling runs, the fish analyzed at the first time showed a low concentration compared to the one analyzed at the second time. The first fish samples analysis showed that TP was very high than TN (see results for fish analysis Table 2).

4.4 Summary of parameter levels in comparison to expected levels in fishponds

An overall assessment was done on the quality of the fishpond water in comparison with other standards or recommended levels for such waters.

Table 3 shows that some parameters exceeded expected standards. The concentration of Nitrates was very high in the fishpond. The effects of nitrates are eutrophication followed by a decrease of water level (Anywanyu and Nathan, 2003), pH fluctuation and low Dissolved Oxygen in the fishpond. This could result in high BOD_5 levels and the disappearance of some aquatic species including fish. The temperature range was favorable for Tilapia but not for Clarias and the pH was favorable for fish growth. The mean Dissolved Oxygen is around required value. The highest concentration was found at the surface where there is natural and photosynthetic re-aeration and was very low at the bottom because it was supposed to be consumed by microorganisms and fish living in the pond. The conductivity is in the range but turbidity exceeded the standards with the measured range between 52-110 NTU.

4.5 Variation between surface and bottom for each parameter

The T-tests were employed to compare water parameters between surface and bottom.

The variation between surface and bottom is neglectable throughout the fish pond for the following parameters: Orthophosphates, NH_4-N, NO_3-N, NO_2-N, TN, pH, conductivity. Only DO and Temperature showed significant differences between the surface and bottom layers of the pond. For stagnant waters it is difficult for oxygen to penetrate into the deeper zone, whereas at the surface it is easily dissolved in water, the same for temperature the radiation cannot penetrate. The difference in turbidity and inflow was significant only at P2 and P6 and this could be attributed to how samples were collected and fish movement.

5. Conclusions and recommendations

5.1 Conclusions

From the results of this study, the following conclusions were made:

1. The TN mean concentration in inflow was 25.1±9 $mg.l^{-1}$ and TP 0.82±0.79 $mg.l^{-1}$. In the pond the mean concentrations were 25.34±5.82 $mg.l^{-1}$ and 1.25±0.95 $mg.l^{-1}$ respectively for TN and TP. In the sediments the mean concentration was 0.2%TN and 236.5 ppm TP. The mean concentration of TN in fish was 8.75% and 8,827 ppm for TP. The assessment of horizontal and vertical distribution in the fishpond showed that nutrients distribution showed a low variability. The pond is small and water was almost stagnant and the inflow was not continuous.

2. It was observed that rabbit droppings contribution per day was 1.7 % TN and 0.47 ppm TP. From urine the concentration per day was 21.7 $mg.l^{-1}$ for TN and 11.55 $mg.l^{-1}$ for TP. The outflow ranged between 25.98 ± 9.46 $mg.l^{-1}$for TN and 9.46±0.8 $mg.l^{-1}$ for TP and these nutrients from the fishpond were used to fertilize the rice plot near the pond.

5.2 Recommendations

From the results and discussions in this report, the following recommendations were derived:

1. It is necessary to identify all controllable sources of nutrients (river sources; rabbit wastes, precipitation) throughout the Rwasave fishponds and develop preventive measures for avoiding excess nutrients and thus avoid contaminating the environment.
2. A research on the nutrient balance might be interesting as it is suspected that ammonia volatilization and denitrification could be the major removal mechanisms of nitrogen.
3. An estimation of nutrient input from seepage and nutrients removal by percolation would be also interesting so that a comparison with inputs could be done.
4. The ponds need to be lined to protect groundwater contamination.
5. A complimentary study on the quantification of water flows failed to take place as originally planned. It is recommended that future studies on nutrients should incorporate a water balance study so that nutrient pathways could be properly characterized, leading to a nutrient mass balance.

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