EFFECT OF FISHPOND INPUT ON POND MUD NUTRIENT LEVELS IN INTEGRATED CROP-FISH CULTURE RESOURCE RECYCLING

by

Fredson J.K Chikafumbwa
National Aquaculture Center
P.O. Box 44
Domasi, Zomba
Malawi

IFS Report for Grant No. A/1776-2

March 1998

FOREWORD

The first two similar experiments were conducted concurrently in 200 m^2 earthen ponds and 5 m^3 concrete tanks from April 18 to October 1995. Ponds were filled with water weekly owing to seepage.

In 1996, sediments from ponds and tanks were used for growing maize (corn) crop as organic fertilizers. In the same year, a decision was made to line the ponds with black plastic sheets to minimize seepage following previous year's experience and trying to determine whether reduced seepage was going to affect the results of the study. The results for the data collected followed similar trends to the first one. However, fish production were lower than the first two similar experiments. This was probably due to low minimum temperatures for most part of the culture period or due to new pond bottom soils brought to the surface during plastic sheet lining and had poor basic fertility.

Data collected is presented in tables. However, for trends some of the data collected with time had been presented in line graphs at the end in appendices, which may be referred to if needed to get more information. The graphs were plotted from means of 3 replicates except for temperature data which were collected from one minimum and maximum thermometer left in water for 24 hours. Temperatures were recorded at 08.00 hours, daily.

Effect of fishpond inputs on pond mud nutrient levels in integrated crop-fish culture resource recycling.

Fredson J.K Chikafumbwa (Grant No. A/1776-2)
National Aquaculture Center
Department of Fisheries
P.O. Box 44,
Domasi, Zomba, Malawi.

Abstract

The success of aquaculture among small holder farmers in Malawi, depends on the use of the available on-farm resources. Commercial fish feeds are currently not available. Fish ponds open possibility for recycling of waste products and nutrient when integrated with crop and/or animals on the farm. The inputs used for growing fish increase the nutrient content of water and sediments. Nutrient rich water can be used for irrigating crops, vegetables and fruits and pond sediments can be used as organic fertilizers

Growth and production of *Tilapia rendalli* and *Oreochromis shiranus* supplied with chicken manure (CM) and CM + maize bran were significantly higher ($P<0.05$) than other treatments (napier grass (NG), NG + urea and no input). Nitrogen, phosphorus and potassium (NPK) are important nutrients in agriculture. Pond water NPK content increased in all treatments with time. Pond mud NPK increased in all treatments receiving inputs and the increase varied between treatments.

Maize (NSCM 41) fertilized with pond mud from ponds receiving CM, NG, NG + urea and control [basal dressed with diammonium phosphate (DAP) + urea, and topdressed with urea] were not significantly different ($P>0.05$) in both biological and economic yields. All were significantly higher ($P<0.05$) than maize grown on normal top soils.

Pond mud can be used as an effective source of organic fertilizer for the growth of crops despite the difference in quality of inputs to fish ponds. The increased nutrient content of pond water further suggest the importance of using fertile pond water for irrigation. Use of fertile pond mud and water can be potentially used as an alternative to expensive inorganic fertilizers

Introduction

Aquaculture is adopted by smallholder fish farmers who are practicing agriculture (crops and livestock) in Malawi. Its success depends on the type of technological packages being developed. Technologies which integrate within the existing systems, utilize and/or recycle waste resources and environmentally friendly are attractive and sustainable to aquaculture development to most resource poor farmers (ICLARM and GTZ 1991). Fish feeds are currently not available and inorganic fertilizers are expensive for smallholder farmers.

Terrestrial and aquatic vegetation, crop waste have been used as a source of feed and organic fertilizers for the culture of tilapias (Chikafumbwa 1990, Jamu 1990). Fish converts plant and animal wastes into high quality protein and enriched pond mud can be used in crop lands. Vegetables and maize have been successfully grown on pond mud previously fed napier grass and/or maize bran [Chimatiro 1992; Chikafumbwa, unpublished; Malikebu (fish farmer), personal communication].

Integration of fish ponds into the existing farming systems improve the efficiency in resource utilization and recycling on the farm (Little and Muir 1987; Brummett and Noble 1995; Prein et al. 1996). Integrated aquaculture started in Asia and had been developing through common sense and gradual approach without scientific documentation. Ponds water have been used for irrigating vegetables, crops and livestock. Crop wastes, vegetable wastes and livestock droppings (feces) and industrial wastes had been used as fish pond inputs. There are wide range of literature on integration of livestock fish; crop-fish; and crop-livestock-fish (Pullin and Shehadeh 1980; Hopkins and Cruz 1982; Little and Muir 1987; Edwards et. al. 1988), however, little is known on nutrient flow (recycling) in various integrated systems. Properly designed integrated systems can help in utilizing and recycling of on-farm resources efficiently.

The objectives of the study were: (a) to investigate the effect of various on-farm fishpond inputs on tilapia (*Tilapia rendalli* and *Oreochromis shiranus*) growth, production and water quality; (b) to investigate the effect of various fishpond inputs [napier grass, chicken manure, and maize (corn) bran] on sediment nutrient [nitrogen (N), phosphorus (P), potassium (K)] build up; (c) to investigate the effect of pond mud (as organic fertilizer) on crop production.

Experiment 1

Effect of different fishpond inputs on the growth and production of *Tilapia rendalli* and *Oreochromis shiranus*; water quality; mud and water nutrients changes with time.

Materials and Methods

Two completely randomized design similar experiments were conducted concurrently in 200 m^2 earthen ponds and 5 m^3 (2.25 X 2.25 X 1 m) concrete tanks, at the National Aquaculture Center, Zomba Malawi. For both experiments, there were five treatments: chicken manure (CM); CM + maize bran; Napier grass (NG); NG + urea; and no input (control). Each treatment were in triplicate earthen ponds and triplicate concrete tanks, respectively, for a period of 168 days.

On 18 April 1995, each pond was randomly stocked with a mixed-sex polyculture of 200 *T. rendalli* and 200 *O. shiranus* (total stocking rate of 2 m^{-2}). Fish were stocked at the individual mean body weights (MBW $\pm$ SD) of 6.7 $\pm$ 0.4 g for *T. rendalli* and 6.8 $\pm$ 0.5 g *for O. shiranus*. In tanks, a mixed-sex polyculture of 8 *T. rendalli* and 8 *O. shiranus* per tank were stocked at a density of 3.2 m^{-2}. Individual mean body weights were 11.8 $\pm$ 0.4 g for *T. rendalli* and 11.0 $\pm$ 0.2 g for *O. shiranus*.

Air dried chicken manure was given at 350 kg dry matter (DM) $ha^{-1}week^{-1}$. Fresh napier grass (*Pennisetum purpureum*) was chopped into approximately 10 cm pieces and given once a day at 50 kg DM $ha^{-1}day^{-1}$. Maize bran was given daily at 3% fish body weight and was adjusted at 4 week intervals at each sampling as a supplement to chicken manure treatment. Urea (inorganic fertilizer) was applied weekly at 4.5 kg ha^{-1} (2 kg N $ha^{-1}week^{-1}$) as a supplement to napier grass treatment. In ponds, water loss owing to evaporation and seepage was replaced weekly to maintain the water level. In tanks, water loss owing mainly to evaporation was replaced once a month.

In both ponds and tanks, fish were sampled every 4 weeks using seine net with 0.5 centimeters mesh. Fish were weighed (g); total and standard length (cm) measured. Ten percent (20 *T. rendalli* and 20 *O. shiranus*) of the total number of fish stocked in ponds and 90-100% of those stocked in tanks were measured at each sampling.

Water quality parameters monitored ware: maximum and minimum water temperatures (°C) daily, dissolved oxygen concentrations (using a YSI Model 57 oxygen meter, Yellow spring Instrument Inc., Ohio) every 2 weeks at 05.00 h; pH (using Hach one pH meter, Loveland Colo, USA) every 2 weeks; electrical conductivity every 2 weeks, alkalinity every 4 weeks according to standard methods (APHA, 1985).

Initial pond bottom soil (sediment) samples were collected immediately after pond water filling for nitrogen (N), phosphorus (P) and potassium (K) analysis. There were no sediments at the bottom of the concrete tanks at the beginning of the study. Two subsequent pond and tank sediment samples were also randomly collected during mid and at harvest for NPK at the Geological Survey, P.O. Box 70, Zomba, Malawi.

At the end of the study, ponds and tanks were seined and drained to collect all fish. In ponds, all fish were counted and batch weighed. Total and standard lengths were measured for 20 *T. rendalli* and 20 *O. shiranus* per pond. All fry/fingerlings were collected and batch weighed. In tanks all fish were weighed and total and standard lengths measured.

Final weight, specific growth rates, daily growth rates, fish production, water and sediment nutrients were subjected to one-way analysis of variance using statistica computer program. Differences between treatment means were tested for significance ($P<0.05$) using Turkey's test (Zar 1984).

Follow-up experiment

Follow-up experiment was conducted in 200 m^2 ponds. Ponds were lined with black plastic sheets at the bottom and was lined up to 0.5 meters on the pond dike. Plastic sheets were covered with soil to a depth of 15 cm to avoid damage when walking in the ponds during sampling. Plastic sheets were lined to minimize water seepage from the ponds.

The experiment was conducted for a period of 154 days, from 28 February to 1 August 1997. There were five treatments and were randomly allocated in triplicates as follows: chicken manure; napier grass; urea; no input; and a combination of napier grass + urea. Mixed-sex polyculture of *T. rendalli* and *O. shiranus* were randomly stocked at a density of 2 m^{-2} (200 *T. rendalli* and 200 *O. shiranus* per pond). Individual mean body weight for *T. rendalli* were 7.1 $\pm$ 0.2 g, while for *O. shiranus* were 5.8 $\pm$ 0.1 g. All other materials and methods were similar to the first similar experiments conducted in 200 m^2 ponds and 5 m^3 concrete tanks above.

Results

Experiment 1a

Production data for ponds are shown in Table 1a. Survival for *T. rendalli* ranged from 75% to 91% and that for *O. shiranus* ranged from 86% to 93%. Highest mean harvest body weights (42.4 g for *T. rendalli* and 42.9 g for *O. shiranus*), specific growth rates (1.08% day^{-1} for *T. rendalli* and 1.09% day^{-1} for *O. shiranus*), daily growth rates (0.21 g day^{-1} for *T. rendalli* and 0.21 g day^{-1} for *O. shiranus*), and extrapolated net yields were obtained in polyculture ponds receiving chicken manure (2,099 kg ha^{-1} $year^{-1}$), and were significantly higher (*P<0.05*) than other treatments. Lowest were obtained in no input control. The contribution of fry and fingerlings to net yields averaged 30.8 $\pm$ 4.8%.

Maximum water temperatures averaged 25.8 °C (ranged from 21 to 31 °C) and minimum water temperatures averaged 18.8 °C (ranged 15 to 23 °C). All water quality parameters monitored were not significantly different (*P>0.05*) between treatments receiving inputs

Table 1a. Summary of yield parameter for *Tilapia rendalli* and *Oreochromis shiranus* stocked in 1:1 polyculture fed chicken manure (CM), napier grass (NG), and combination of CM + maize bran and NG + urea fertilizer in 200 m^2 earthen ponds for 168 days. Figures in the same row having the same letter superscript are not significantly different ($P>0.05$). Mean of 3 replicates.

	Treatments				
	Chicken manure	**No input**	**Chicken manure + maize bran**	**Napier grass**	**Napier grass + urea**
No. of fish per pond at stocking	400	400	400	400	400
Initial weight (g)					
T. rendalli	6.7	6.2	6.6	7.2	7.2
O. shiranus	6.9	6.2	6.9	6.4	7.7
Final weight (g)					
T. rendalli	41.4^a	19.6^b	40.2^a	21.0^b	22.2^b
O. shiranus	42.9^a	22.1^b	38.0^a	23.4^b	21.6^b
Survival (%)					
T. rendalli	91	83	87	75	90
O. shiranus	93	86	86	88	92
Specific growth rates (% day^{-1})					
T. rendalli	1.08^a	0.69^b	1.08^a	0.64^b	0.67^b
O. shiranus	1.09^a	0.76^b	1.02^a	0.77^b	0.61^c
Daily growth rate (g day^{-1})					
T. rendalli	0.21^a	0.08^b	0.20^a	0.08^b	0.09^b
O. shiranus	0.21^a	0.09^b	0.19^a	0.10^b	0.08^b
Production per pond (kg)					
T. rendalli	7.53	3.25	6.99	3.15	4.00
O. shiranus	7.98	3.80	6.54	4.12	3.97
Recruits	6.53	2.86	4.80	4.66	3.49
Total fish production (kg $pond^{-1}$)	22.0^a	9.91^c	18.3^a	11.9^b	11.4^b
Net fish production (kg $pond^{-1}$)	19.3^a	7.4^d	15.6^b	9.2^c	8.4^c
Net fish production (kg ha^{-1})	966.2^a	371.5^d	781.5^b	460.6^c	424.0^c
Net fish production (kg $ha^{-1} \cdot year^{-1}$)	2099.2^a	807.6^d	1697.9^b	1000.3^c	921.2^c

but all were significantly different ($P<0.05$) from no input treatment (Table 2a). pH decreased from 7.03 $\pm$ 0.13 to 6.75 $\pm$ 0.16 and dissolved oxygen (05.00 h) decreased from 5.43 + 0.12 to 1.78 $\pm$ 0.52 mg l^{-1}. Electrical conductivity decreased from 77 $\pm$ 29 to 46 $\pm$ 11 micro mho cm^{-1}. Alkalinity increased with time from 13.5 $\pm$ 1.7 to 27.5 by day 84 and decrease to 22.7 $\pm$ 2.2 mg l^{-1} as $CaCO_3$ by day 168. Chlorophyll *a* concentrations increase varied among treatments, however, there were no significant differences ($P>0.05$) between treatments. Highest chlorophyll *a* concentrations were reached on day 56.

Napier grass nutrients [nitrogen (N), phosphorus (P_2O_5), and potassium (K)] content were 2.2 %N, 0.31 %P_2O_5 and 1.43 %K, respectively; and for chicken manure were 2.54 %N, 4.18 %P_2O_5 and 1.61 %K, respectively. Initial and final pond sediment nutrients are shown in Table 3a. Nitrogen decreased in all treatments. The decrease in CM + maize bran treatment were significantly different ($P<0.05$) from other treatments. Phosphorus increase in napier grass (from 0.03 to 0.25 %P_2O_5) treatments were significantly different ($P<0.05$) ($P<0.05$) from other treatments. Potassium increase varied in all treatments from 2.18 $\pm$ 0.21 to 2.61 $\pm$ 0.41 %K.

Initial and final pond water nutrients (NPK) are shown in Table 4a. Nitrogen concentration increased in all treatment. Final water nitrogen concentrations increase in napier grass (11.34 ppm N) and no input (11.30 ppm N) control and were significantly higher ($P<0.05$) than other treatments. Phosphorus and potassium concentrations increased in all treatments, and the increase in CM + maize bran (phosphorus, 0.07 %P_2O_5; potassium, 3.00 ppm K, respectively) were significantly higher ($P<0.05$) than other treatments.

Table 2a. Effect of different inputs (chicken manure; CM + maize bran; napier grass; NG + urea) and no input in 200 m^2 earthen ponds on pH, dissolve oxygen concentrations (DO), electrical conductivity (EC) alkalinity, and chlorophyll a for 168 days

Water quality parameter		Treatments receiving inputs	No input
	Initial value	Final value	Final value
pH	7.03 ± 0.13	6.75 ± 0.16	7.2
DO	5.43 ± 0.12	1.78 ± 0.52	6.0
EC	77 ± 29	46 ± 11	79
Alkalinity	13.5 ±1.7	27.5 ± 0.2	15.4 ± 0.2
Chlorophyll a	0	80 ± 34	35 ± 13

Note: Values for treatments receiving inputs were ramped together because there were no significant differences ($P>0.05$) between them and were significantly different ($P<0.05$) from on input treatment

Table 3a. Effect of applying chicken manure (CM), CM + maize bran, napier grass (NG), NG + urea and no input in 200 m^2 earthen ponds stocked with 1:1 polyculture of *Tilapia rendalli* and *Oreochromis shiranus* on pond sediment nutrient (nitrogen, phosphorus and potassium) for 162 days. Figures in the same column having the same letter superscript are not significantly different ($P>0.05$). Mean of 3 replicate.

	Nitrogen (%N)		Phosphorus (% P_2O_5)		Potassium (%K)	
Treatment	Initial	Final	Initial	Final	Initial	Final
Chicken Manure	0.19	0.15^{a}	0.03	0.22^{a}	2.30	3.15^{a}
CM + maize bran	0.20	0.06^{c}	0.03	0.13^{c}	2.00	2.08^{c}
Napier grass	0.19	0.12^{b}	0.03	0.25^{a}	2.30	2.80^{b}
NG + urea	0.19	0.11^{b}	0.02	0.14^{c}	1.90	2.33^{c}
no input	0.20	0.17^{a}	0.03	0.19^{b}	2.40	2.69^{b}

Table 4a. Effect of applying chicken manure (CM), CM + maize bran, napier grass (NG), NG + urea and no input in 200 m^2 earthen ponds stocked with 1:1 polyculture of *Tilapia rendalli* and *Oreochromis shiranus* on pond water nutrient (nitrogen, phosphorus and potassium) for 162 days. Figures in the same column having the same letter superscript are not significantly different ($P>0.05$). Mean of 3 replicate.

	Nitrogen (ppm)		Phosphorus (%P_2O_5)		Potassium (ppm)	
Treatment	Inlet water	Final	Inlet water	Final	Inlet water	Final
Chicken Manure	1.90	7.60^c	0.01	0.04^b	1.98	2.40^b
CM + maize bran	1.90	9.45^b	0.01	0.07^a	1.98	3.00^a
Napier grass	1.90	11.34^a	0.01	0.02^c	1.98	2.80^a
NG + urea	1.90	7.56^c	0.01	0.02^c	1.98	2.20^b
no input	1.90	11.30^a	0.01	0.02^c	1.98	1.50^c

Experiment 1b

Production data for tank experiment are shown in Table 1b. Highest fish survival for both *T. rendalli* and *O. shiranus* (100%) were obtained in chicken manure treatment and the lowest (92%) were obtained in napier, grass and NG + urea treatments. *T. rendalli* survival ranged from 88 to 100% and *O. shiranus* ranged from 92 to 100% in all treatments. Highest mean harvest body weights (40.9 g), specific growth rates (0.73% day^{-1}), and daily growth rates (0.17 g day^{-1}) for *T. rendalli* were obtained in napier grass treatment and were significantly higher ($P<0.05$) than other treatments; while for *O. shiranus*, the highest mean harvest body weights (59.7 g), specific growth rates (1.00% day^{-1}), and daily growth rates (0.29 g day^{-1}) were obtained in CM + maize bran and were significantly higher ($P<0.05$) than other treatments, except from napier grass treatments. Highest extrapolated net yields were obtained in chicken manure (2,019.6 kg $ha^{-1.}$ $year^{-1}$) and CM + maize bran (2,250.6 kg $ha^{-1.}$ $year^{-1}$) and were significantly higher ($P<0.05$) than other treatments.

Maximum water temperatures averaged 25.0 °C (ranged from 21 to 31 °C) and minimum water temperatures averaged 18.1 °C (ranged 14 to 23 °C). All water quality parameter monitored were not significantly different (*P>0.05*) between treatments receiving inputs, but all were significantly different (P<0.05) from the no inputs treatment (Table 2b).

Table 1b. Summary of yield parameters for *Tilapia rendalli* and *Oreochromis shiranus* stocked in 1:1 polyculture fed chicken manure (CM), napier grass (NG) and combination of CM + maize bran and NG + urea in 5 m^3 concrete tanks for 168 days. Figures in the same row having the same letter superscript are not significantly different (*P>0.05*). Mean of 3 replicates.

	Treatments				
	Chicken manure	**No input**	**Chicken manure + maize ban**	**Napier grass**	**Napier grass + urea**
No. of fish per tank at stocking	16	16	16	16	16
Initial weight (g)					
T. rendalli	12	11.5	11.4	11.9	12.4
O. shiranus	11.1	11.2	11.2	10.8	10.8
Harvest weight (g)					
T. rendalli	28.7^b	26.7^c	29.1^b	40.9^a	29.9^b
O. shiranus	52.5^b	26.0^c	59.7^a	55.9^b	49.8^b
Survival (%)					
T. rendalli	100	92	95	88	92
O. shiranus	100	95	100	95	92
Specific growth rates (% day^{-1})					
T. rendalli	0.52^c	0.50^c	0.56^b	0.73^a	0.52^c
O. shiranus	0.92^b	0.50^c	1.00^a	0.98^a	0.91^b
Daily growth rate (g day^{-1})					
T. rendalli	0.10^b	0.09^b	0.11^b	0.17^a	0.10^b
O. shiranus	0.25^b	0.09^c	0.29^a	0.27^a	0.23^b
Production per tank (kg)					
T. rendalli	0.23	0.20	0.22	0.29	0.22
O. shiranus	0.42	0.20	0.48	0.42	0.37
Recruits	0.00	0.00	0.00	0.00	0.00
Total fish production (kg $tank^{-1}$)	0.65^a	0.39^d	0.70^a	0.42^c	0.59^b
Net fish production (kg $tank^{-1}$)	0.46^a	0.21^d	0.52^a	0.24^c	0.40^b
Net fish production (kg ha^{-1})	929.6^a	425.0^d	1035.9^a	486.4^c	801.9^b
Net fish production (kg $ha^{-1} \cdot year^{-1}$)	2019.6^a	923.4^d	2250.6^a	1056.9^c	1742.4^b

Table 2b. Effect of different inputs (chicken manure; CM + maize bran; napier grass; NG + urea) and no input in 5 m^3 concrete tanks on pH, dissolve oxygen concentrations (DO), electrical conductivity (EC) alkalinity, and chlorophyll a for 168 days

Water quality parameter		Treatments receiving inputs	No input
	Initial value	**Final value**	**Final value**
pH	9.0 ± 0.5	7.8 ± 0.3	9.4 ± 0.01
DO	6.8 ± 0.6	1.1 ± 0.3	6.9 ± 0.5
EC	88 ± 10	158 ± 11	92 ± 12
Alkalinity	22.3 ± 3.7	115.4 ± 10.6	68.1 ± 8.9
Chlorophyll a	0	156 ± 12	80 ± 11

Note: Values for treatments receiving inputs were ramped together because there were no significant differences (P>0.05) between them and were significantly different (P<0.05) from on input treatment

pH decreased from 9.0 ± 0.5 to 7.8 ± 0.3; dissolved oxygen concentrations (05.00 h) decreased from 6.8 ± 0.6 to 1.1 ± 0.3 mg l^{-1}; electrical conductivities increased from 88 ± 10 to 158 ± 11 micro mho cm^{-1}; and alkalinities increased from 22.3 ± 3.7 to 115.4 ± 10.6 mg l^{-1} by day 168. Chlorophyll *a* concentrations increase varied among treatments and the highest was obtained in chicken manure (156 ± 12 mg l^{-1}) and lowest was in no input (92 ± 44 mg l^{-1}) at harvest, but were not significantly different (*P>0.05*) .

Initial and final tank sediment nutrients are shown in Table 3b. Sediment nitrogen, phosphorus, and potassium increased in all treatments. At harvest nitrogen concentrations were significantly higher (*P<0.05*) in CM + maize bran (2.86% N) than other treatments. Sediment phosphorus (1.34% P_2O_5) and potassium (0.83%) were significantly higher (*P<0.05*) in tanks receiving chicken manure than other treatments.

Tank water nitrogen, phosphorus and potassium (NPK) concentrations are shown in Table 4b. Nitrogen, phosphorus and potassium concentrations increased in all treatment. The increase in NPK concentrations were significantly higher (*P<0.05*) in tanks receiving CM + maize bran than other treatments.

Table 3b. Effect of applying chicken manure (CM), CM + maize bran, napier grass (NG), NG + urea and no input in 5 m^3 concrete tanks stocked with 1:1 polyculture of *Tilapia rendalli* and *Oreochromis shiranus* on tank sediment nutrient (nitrogen, phosphorus and potassium) for 162 days. Figures in the same column having the same letter superscript are not significantly different ($P>0.05$). Mean of 3 replicate

Treatment	Nitrogen (%N) Initial	Nitrogen (%N) Final	Phosphorus (%P_2O_5) Initial	Phosphorus (%P_2O_5) Final	Potassium (%K) Initial	Potassium (%K) Final
Chicken Manure	-	2.01^b	-	1.34^a	-	0.83^a
CM + maize bran	-	2.86^a	-	1.05^b	-	0.39^b
Napier grass	-	1.27^c	-	0.35^d	-	0.41^b
NG + urea	-	1.41^c	-	0.14^d	-	0.42^b
no input	-	2.13^b	-	0.85^c	-	0.78^a

Note:
- sediments were not available for collection at the bottom of the concrete tanks at the beginning of the study

Table 4b. Effect of applying chicken manure (CM), CM + maize bran, napier grass (NG), NG + urea and no input in 5 m^3 concrete tanks stocked with 1:1 polyculture of *Tilapia rendalli* and *Oreochromis shiranus* on tank water nutrient (nitrogen, phosphorus and potassium) for 162 days. Figures in the same column having the same letter superscript are not significantly different ($P>0.05$). Mean of 3 replicate.

Treatment	Nitrogen (ppm) Inlet water	Nitrogen (ppm) Final	Phosphorus (%P_2O_5) Inlet water	Phosphorus (%P_2O_5) Final	Potassium (ppm) Inlet water	Potassium (ppm) Final
Chicken Manure	1.90	11.32^b	0.01	0.17^b	1.98	15.00^b
CM + maize bran	1.90	17.96^a	0.01	0.29^a	1.98	23.00^a
Napier grass	1.90	9.45^c	0.01	0.04^c	1.98	22.10^a
NG + urea	1.90	7.60^c	0.01	0.05^c	1.98	23.50^a
no input	1.90	13.21^b	0.01	0.01^d	1.98	3.80^c

In tanks, final sediments nitrogen and phosphorus were higher than those obtained in ponds, but sediments potassium were lower than that obtained in ponds (Table 3a. and b.). Highest sediments nitrogen were obtain in CM + maize bran treatment, while phosphorus and potassium were obtained in chicken manure treatments. No input sediments had also higher nitrogen, and potassium than in tanks receiving napier grass, NG + urea and chicken manure.

Experiment 1c

Production data is shown in Table 1c. Fish survival ranged from 81 to 95% for *T. rendalli* and 77 to 95 for *O. shiranus*. Lowest survival for *O. shiranus* were obtained in no input and NG + urea treatments; while that of *T. rendalli* was obtained in NG + urea treatment. Highest mean harvest body weights, specific growth rates, net fish production for *T. rendalli* and *O. shiranus* were obtained in chicken manure and NG + urea and were significantly higher ($P<0.05$) than other treatments.

Maximum water temperatures were 27.3 ± 3.0 °C (ranged from 23 to 31 °C) and minimum were 16.5 ± 3.7 °C (ranged from 12 to 21 °C). Nitrogen, phosphorus, and potassium are shown in Table 3c. Nitrogen concentrations did not change in most treatments and decreased in some treatments while phosphorus and potassium increased in all treatment.

Discussion

Fish production obtained in a polyculture of *T. rendalli* and *O. shiranus* using chicken manure and CM + maize bran inputs in ponds and tanks in this study were similar to what was reported by Chikafumbwa et al. (1993) using a combination of napier grass and maize bran inputs to monocultures of either species, however, these were lower than a 1 : 1 polyculture of *T. rendalli* and *O. shiranus* (3,013 kg ha^{-1}. $year^{-1}$). Scholz et al. (1997) reported increase in fish yields among smallholder farmers in Malawi from around less 500 kg ha^{-1} in 1990 to over 1,300 kg in 1996; he also reported increased integration (crops and livestock diversification) due to fish ponds introduction on smallholder farms and increased recycling of on-farm resources. Higher tilapia yields can be obtained using on-farm low quality inputs. Hassan et al. (1997) reported higher tilapia (*O. niloticus*) yields of 3.83 tons $ha^{-1}year^{-1}$ when supplemented cattle manure with urea and triple super phosphate, and much higher yields were obtained when high quality poultry manure were used, e.g. duck manure, 10.4 tons $ha^{-1} \cdot year^{-1}$ (AIT 1986); chicken manure, 4.28 tons $ha^{-1} \cdot year^{-1}$ (Green et al. 1989)

Table 1c. Summary of yield parameter for *Tilapia rendalli* and *Oreochromis shiranus* stocked in 1:1 polyculture fed chicken manure (CM), napier grass (NG), urea, and combination of NG + urea fertilizer in 200 m^2 earthen ponds for 154 days. Figures in the same row having the same letter superscript are not significantly different ($P>0.05$). Mean of 3 replicates.

	Treatments				
	Chicken manure	**No input**	**Urea**	**Napier grass**	**Napier grass + urea**
No. of fish per pond at stocking	400	400	400	400	400
Initial weight (g)					
T. rendalli	7.0	7.0	6.9	7.4	7.2
O. shiranus	5.7	5.9	5.6	5.9	5.7
Final weight (g)					
T. rendalli	24.2^a	18.4^b	15.9^b	24.3^a	25.3^a
O. shiranus	32.4^a	15.7^c	24.6^b	18.8^c	31.5^a
Survival (%)					
T. rendalli	94	86	85	95	81
O. shiranus	83	77	95	86	78
Specific growth rates (% day^{-1})					
T. rendalli	0.81^a	0.55^b	0.51^b	0.77^a	0.81^a
O. shiranus	1.12^a	0.65^c	1.02^b	0.75^c	1.11^a
Daily growth rate (g day^{-1})					
T. rendalli	0.15^a	0.07^c	0.06^c	0.11^b	0.12^b
O. shiranus	0.17^a	0.06^c	0.12^b	0.08^c	0.17^a
Production per pond (kg)					
T. rendalli	4.55	3.16	2.70	4.62	4.10
O. shiranus	5.31	2.41	4.67	3.23	4.90
Recruits	1.63	0.41	1.93	0.85	1.83
Total fish production (kg $pond^{-1}$)	11.5^a	6.0^c	9.3^b	8.7^b	10.8^a
Net fish production (kg $pond^{-1}$)	9.0^a	3.4^c	6.5^b	6.1^b	8.3^a
Net fish production (kg ha^{-1})	450.0^a	170.0^c	325.0^b	305.0^b	415.0^a
Net fish production (kg $ha^{-1} \cdot year^{-1}$)	1066.6^a	402.9^c	770.2^b	722.9^b	983.6^a

Table 3c. Effect of applying chicken manure (CM), napier grass (NG), urea, and a combination of NG + urea in 200 m^2 earthen ponds stocked with 1:1 polyculture of *Tilapia rendalli* and *Oreochromis shiranus* on pond sediment nutrients (nitrogen, phosphorus and potassium) for 152 days. Figures in the same column having the same letter superscript are not significantly different (*P>0.05*). Mean of 3 replicate.

	Nitrogen (%N)		Phosphorus (%P_2O_5)		Potassium (%K)	
Treatment	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
Chicken Manure	0.13	0.13	0.02	0.16	2.00	3.52
No input	0.11	0.14	0.02	0.19	2.00	3.23
Urea	0.18	0.14	0.02	0.16	1.00	3.09
Napier grass	0.15	0.16	0.02	0.17	1.00	3.00
NG + urea	0.13	0.17	0.02	0.23	2.00	3.00

Fish production from ponds and tanks receiving individual inputs (chicken manure or napier grass) were similar, however when these inputs were combined (CM + maize bran; NG + urea) fish production increased in tanks while in ponds production decreased. The increase of fish production in tanks was due to higher productive environment than in ponds where electrical conductivity decreased due to seepage. Water quality parameters were within the acceptable productive range (Boyd 1987). However, DO were lower and may have equally affected fish growth in treatments receiving inputs and low DO may have been for a short time at the early morning hours and had minor effect on fish growth and mortality.

In experiment 1c, similar trend to the first two similar experiment on fish production, water quality and nutrients changes in the mud were obtained in ponds. However, fish production were lower than the first two despite lining ponds bottom with plastic sheets and reduced water seepage. This was probably due to turning bottom soils to the top which were poor in basal nutrients during plastic lining and low minimum water temperatures of less than 20 °C for the greater part of the culture period (Bishai 1965; Fryer and Iles 1972; Huet 1972). Probably, they needed liming before stocking the fish.

Nitrogen, phosphorus and potassium are primary nutrients in fertilizers. In ponds, nitrogen and phosphorus are important nutrient, while potassium is normally considered as unimportant nutrient (Moyle 1946; Arce and Boyd 1980; Boyd 1982). Stachowicz et al (1994) reported increased nitrogen, phosphorus and potassium in periods of external loading and phytoplankton dominance in ponds. In this study, the decrease of nitrogen occurred during decomposition of the organic inputs (chicken manure and napier grass) settled at the pond bottom (sediment). The organic input were decomposing, releasing nitrogen (ammonia, NH_3 and ammonium NH_4^+), which dissolved in water, nitrates (NO_3^-) and nitrite (NO_2^-) were lost through denitrification. Phosphorus increased in pond sediments during degradation of applied organic inputs to ponds. When the organic inputs were decomposing (orthophosphate), soluble organic phosphorus were being released and absorbed by phytoplankton. The unused precipitated as insoluble calcium or aluminium phosphate to pond mud (sediment). Potassium increased in pond sediments during organic inputs degradation. Released potassium ions (K^+) dissolved in water not absorbed by phytoplankton remained in solution or participated in ion exchange reaction with sediments. High values of nitrogen, phosphorus and potassium in pond and tank water were due to the dissolving of these nutrients during decomposition of the inputs applied.

Experiment 2

Effect of sediments from ponds/tanks receiving different inputs (chicken manure, CM + maize bran, napier grass + urea) on maize production.

Materials and methods

At fish harvest, ponds and tanks were drained. After one week, sediments were collected from 200 m^2 earthen ponds and concrete [1]tanks and kept separately according to treatments (chicken manure (CM); CM + maize bran; napier grass (NG); and NG + urea). All collected sediments were sun-dried before taking the samples for nitrogen, phosphorus and potassium analyses.

Eighteen, 7 m^2 plots, were prepared for growing maize (NSCM 41). Plots were randomly located to the following input treatments: (i) CM sediments; (ii) NG sediments; (iii) NG + urea sediments; (iv) diammonium (DAP) and urea inorganic fertilizers[2]; and (v) normal top soil (control). Each treatment receiving sediments from ponds and inorganic fertilizers were randomly located in triplicate plots; and plots receiving sediments (CM; NG; and NG + urea) from concrete tanks[3] were randomly located in one replicate plots. Plots receiving sediments were applied with one wheel barrow full of sediments, spread and thoroughly mixed with soil. DAP and urea were applied as basal dressing after maize germination and urea was top dressed when maize was knee high following the standard methods (MOA 1993-1994). At harvest, final soil samples were randomly collected from all plots. Initial and final soil and sediment samples were collected for nitrogen, phosphorus and potassium analyses. All sediments sample were analyzed at the Geological Surveys Department, P.O. Box 27, Zomba, Malawi.

At harvest, whole maize plants were cut and sun dried. Later, maize grain were separated for the determination of economic yield. Samples for whole plants (biological yield), and

[1] Sediments were not collected at the bottom of concrete tanks at the beginning of the experiment.
[2] DAP and urea used as control for the commonly used inorganic fertilizer in Maalawi
[3] Not enough sediments in tanks for replicated treatments

grain were oven dried at 70 °C to a constant weight (approximately 48 hours) and then calculated to 10% moisture.

Data collected were exposed to one way analysis of variance (ANOVA) using Statistica computer program. The difference between means were isolated using Tukey's test.

Results

Yields of maize (NSCM 41) grown on pond and tank sediments, inorganic fertilizers and normal soil are shown in Table 5. Biological and economic yields of maize grown on pond sediments from ponds receiving chicken manure, napier grass and NG + urea were not significantly different ($P>0.05$) from maize grown on DAP and urea inorganic fertilizer. All treatments were significantly different ($P<0.05$) from maize grown on normal soil (control). Similarly, biological and economic maize yields obtained from maize grown on tank sediments receiving chicken manure, napier grass, and NG + urea were not significantly different ($P>0.05$) from maize grown DAP and urea on inorganic fertilizers.

Initial and final nutrient contents of sediments and soils are shown in Table 6. Nitrogen and phosphorus decreased in all treatments during maize growing period, except in the control where there was an increase in nitrogen concentrations. Potassium increased in all treatments, except in chicken manure treatment where it decreased.

Discussion

Maize (NSCM 41) potential yields, when supplied with sufficient nutrients, is 5.5 ton ha^{-1} (MOA 1993 1994). Nitrogen, phosphorus and potassium are important nutrients for agricultural crops. The yields obtained from plots fertilized with pond sediments (7.5 to 9.1 ton ha^{-1}) were not significantly different from maize supplied with recommended inorganic fertilizers (7.4 ton ha^{-1}) and were higher than the potential yield. Chimatiro (1992) also reported higher yields (30 ton ha^{-1}) of head cabbage grown on pond sediments (sediments from fish ponds receiving napier grass and maize bran) than those obtained at

Table 5. Effect of sediments from (a) ponds and (b) tanks receiving chicken manure (CM), napier grass (NG), NG + urea (NGU), and controls (diammonium phosphate (DAP) + urea fertilizer; and normal soil) on maize economic and biological yield grown in 7 m^2 plots at the National Aquaculture Center, Malawi.

(a) Pond sediments. Figures in the same row having the same letter superscript are not significantly different (*P>0.05*). Mean of 3 replicates.

	Chicken manure	Napier grass	Napier grass + urea	DAP + urea	Normal soil
Biological yield					
whole maize plant (kg 7 m^{-2})	11.57^a	10.02^a	9.33^a	9.28^a	4.60^b
tons ha^{-1}	16.5^a	14.3^a	13.3^a	13.3^a	6.6^b
Economic yield					
maize grain (kg 7 m^{-2})	6.41^a	5.69^a	5.25^a	5.22^a	2.18^b
tons ha^{-1}	9.1^a	8.1^a	7.5^a	7.4^a	3.0^b

(b) Tank sediments. (One replicate)

	Chicken manure	Napier grass	Napier grass + urea	DAP + urea	Normal soil
Biological yield					
whole maize plant (kg 7 m^{-2})	11.80	9.60	9.50	9.28	4.60
tons/ha.	16.8	13.7	13.5	13.3	6.6
Economic yield					
maize grain (kg 7 m^{-2})	7.10	5.50	5.35	5.22	2.18
tons. ha^{-1}	10.1	7.8	7.6	7.4	3.0

Note: One replicate because the sediments were not adequate for replication.
Calculated at 10% moisture content

Table 6. Changes in nitrogen (N), phosphorous (P_2O_5) and potassium (K) in maize plots with time, supplied with sediments from (a) ponds and (b) tanks receiving chicken manure, napier grass + urea and napier grass.

(a) Pond sediments (mean of 3 replicates)

Sediment made from	Nitrogen (%N)		Phosphorus (% P_2O_5)		Potassium (%K)	
	Initial	Final	Initial	Final	Initial	Final
Chicken manure	0.29	0.02	0.25	0.15	2.66	1.43
Napier grass + Urea	0.25	0.16	0.18	0.12	2.06	2.33
Napier grass	0.48	0.34	0.28	0.19	2.11	2.33
Normal top soil	0.11	0.15	0.13	0.09	2.36	2.63

(b) Tank sediments. (one replicate).

Sediment made from	Nitrogen (%N)		Phosphorus (% P_2O_5)		Potassium (%K)	
	Initial	Final	Initial	Final	Initial	Final
Chicken manure	0.97	0.14	1.60	0.12	3.47	2.89
Napier grass + Urea	0.21	0.18	0.18	0.18	1.94	2.33
Napier grass	0.24	0.08	0.55	0.05	2.93	1.79
Normal top soil	0.11	0.15	0.13	0.09	2.36	2.63

Chitedze Research (27 ton ha^{-1}) supplied with nutrients from inorganic fertilizers. This suggested that pond sediments supplied the nutrient required by the maize plants throughout the growing period. Sediments nitrogen at fish harvest were low, however, after storage and sun-dried for some time, nitrogen increased through nitrogen fixation from the atmosphere and decomposition of organic materials, detritus, benthos and other organisms in the sediments.

Pond sediments were applied at planting time only, but they managed to sustain the growth of maize to maturity. Sediments were releasing nutrients continuously throughout the maize growing period due to decomposition of detritus, benthos and other organisms in the sediments. Nitrogen and phosphorus decreased with time in all maize plots received sediments because they were being effectively absorbed by health maize plants, but potassium increased was because most soils in Malawi are reach in potassium. Potassium available in sediments applied added to existing potassium in the soils. Nitrogen increase on normal top soils were probably due to decomposed organic matter organic matter and inefficient utilization of nutrients by the unhealthy maize crop.

In conclusion, ponds can play a pivotal role in integrated aquaculture-agriculture in resource recycling. Resources can be efficiently utilized through recycling on the farm. Ponds convert wastes, by-products and other materials into high quality animal protein (fish) and organic fertilizers (pond mud) for crops and vegetables. Maize production in this study and previous studies demonstrated that regardless of the source and quality of inputs, pond sediments were equally efficient in supplying nutrients for the growth of crops and vegetables. Pond water receiving various inputs can provide nutrients to crops and vegetable when used for irrigation.

Use of pond mud can provide an alternative to inorganic fertilizers. Inorganic fertilizers are becoming expensive and have negative effect on soil fertility in the long run through decreasing soil pH and destruction of soil structure. Pond mud, however, can maintain high soil fertility and can be easily used in crop fields and vegetable gardens near the pond. The limitation is high labor cost for removing pond mud, and transporting to crop field far away from pond. Ponds are limited to places where there is sufficient water supply.

Acknowledgments

This study was supported by the International Foundation for Science (IFS) under Grant No. A/1776-2, and the International Center for Living Aquatic Resources Management (ICLARM). The author would like to thank the Geological Surveys staff for the assistance in samples analyses. My sincere thanks also go to Dr. Randall Brummett for his personal support during the study and Mrs. Patience Kananji for taking care of the finances, purchase required items and making all payments on time when required.

References

AIT (Asian Institute of Technology). 1986. Buffalo/fish and duck/fish integrated systems in small-scale farmers at the family level. AIT Research Report No. 198. Asian Institute of Technology, Bangkok, Thailand.

Arce, R.G. and Boyd, C.E. 1980. Water chemistry of Alabama ponds. Auburn University Agricultural Experiment Station, Auburn University, Alabama, USA. Bulletin 522, 35 pp.

Bishai, H.M. 1965. Resistance of Tilapia niloticus 1. to high temperature. Hydrobiologia, 25: 473-488.

Boyd, C.E. 1982. Water quality management for pond fish culture. Development in aquaculture and fisheries Science, 9. Elsevier Scientific Publishing Company, Amsterdam-Oxford-New York. 318 pp.

Brummett, R.E. and R. Noble. 1995. Aquaculture for African smallholders. ICLARM Techn. Rep. 46, 69 pp.

Chikafumbwa, F.J.K., Costa-Pierce, B.A., Jamu, D.M., and Kadongola, W.K. 1993. Investigations on the use of on-farm resources as pond inputs to culture *Tilapia rendalli* and *Oreochromis shiranus* on smallholder farms in rural Malawi. Aquaculture, 117: 261-271.

Chimatiro, S.K. 1992. The ecology of smallholder fish farms of Zomba District, Malawi. 144 pp. Msc. Thesis, University of Malawi, Zomba, Malawi.

Edwards, P., Pullin, R.S.V. and Gartner, J.A. 1988. Research and education for the development of integrated crop-livestock farming systems in the tropics. ICLARM Studies review 16, 53 p. International Center for Livimg Aquatic Resources Management, Manila, Philippines.

Fryer, G. and T..D. Iles. 1972. The cichlid fishes of the great lakes of Africa. Their biology and evolution. Oliver and Boyd; Edinburgh. 641 p.

Green, W.B., R.P. Phelps and H.R. Alvarenga. 1989. The effect of manures nd chemical fertilizers on the production of Oreochromis niloticus in earthen ponds. Aquaculture 76: 37-42.

Huet, M. 1972. Textbook of fish culture breeding and cultivation of fish. Fish News (Books) Ltd: West by fleet, Surrey, 436 p.

ICLARM and GTZ, 1991. The context of small-scale integrated agriculture-aquaculture systems in Africa: a case study of Malawi. ICLARM Stud. Rev. 18, 308 pp.

Hassan, S., P. Edwards and D.C. Little. 1997. Comparison of tilapia monoculture and carp polyculture in fertilized earthen ponds. J. of World Aquaculture Society 28(3): 268-274.

Little, D. and Muir, J. 1987. A guide to integrated warm water aquaculture. Institute of aquaculture, University of Stirling, Stirling FK9 4LA, 238 pp.

Hopkins, K.D. and Cruz, E.M. 1982. The ICLARM-CLSU integrated animal-fish farming project: final report. ICLARM Technical Reports 5, 96 p. International Center for Living Aquatic Resources Management, Manila and Freshwater Aquaculture Center, Central Luzon State University, Nueva, Philippines.

Moyle, J.B. 1946. Some indices of lake productivity. Trans. Amer. Fish. Soc. , 76: 322-334.

MOA (Ministry of Agriculture) 1993-1994. Guide to agricultural production Malawi. Agricultural Communication Branch, Ministry of Agriculture, Lilongwe, Malawi, 225 pp.

Prein, M., J.K. Ofori and C. Lightfoot, Editors. 1996. Research for the future development of aquaculture in Ghana. ICLARM Conf. Proc. 42, 94 pp.

Pullin, R.S.V. and Z.H. Shehadeh, Editors. 1980. Integrated agriculture-aquaculture farming systems. ICLARM Conference Proceedings 4, 258 p. International Center for Living Aquatic Resources Management, Manila and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture, College, Los Banos, Laguna, Philippines.

Scholz, U.F., S.K. Chimatiro and M. Hammel. 1997. Status and prospects of aquaculture development in Malawi, a case of MAGFAD: is there sustainability and future. Presented at the First Reional Conference on Aquaculture, Bunda College of Agriculture, University of Malawi, Lilongwe, Malawi, 17-19 Novemeber, 1997.

Stachowicz, K., M. Czernoch and E. Dubiel. 1994. Field pond as a sink for nutrients migrating from agrocenoses to freshwater. Aquatic Sciences 56(4): 363-375.

Appendices

Appendix 1 : Tilapia rendalli and Oreochromis shiranus growth figure

Appendix 2: Mean minimum and maximum temperatures during fish culture period

Appendix 3: Dissolved oxygen concentration trends figure

Appendix 4: Chlorophyll a trends figure

Appendix 5: Alkalinities trends figure

Appendix 6: Conductivities trends figure

Appendix 1.

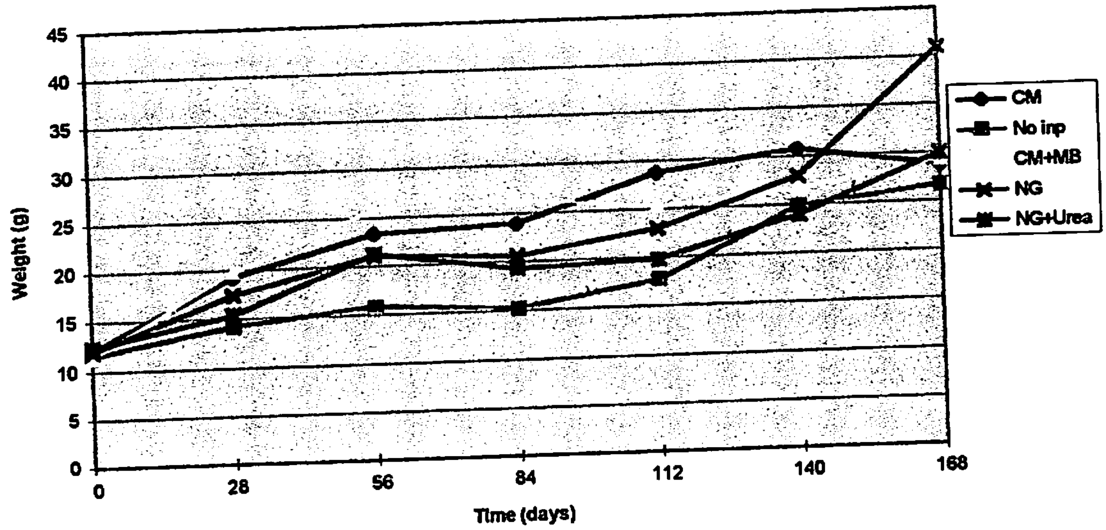

Figure 1a. Effect of chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG + urea and no imput on the growth of *T. rendalli* in the polyculture in 5 m3 concrete tanks for 168 days.

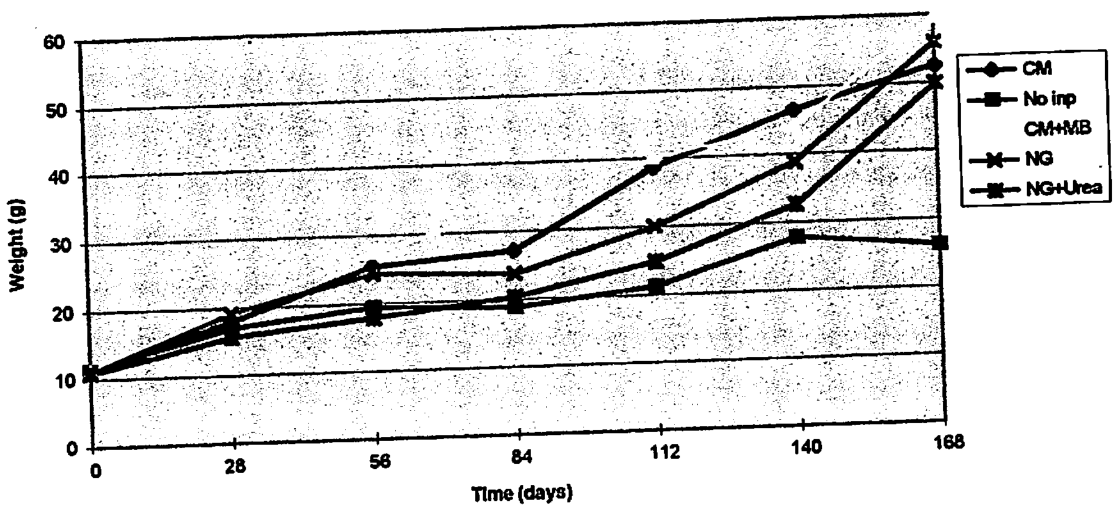

Figure 1b. Effect of chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG + urea, and no input on the growth of *O. shiranus* in 5 m3 concrete tanks for 168 days

Appendix 2

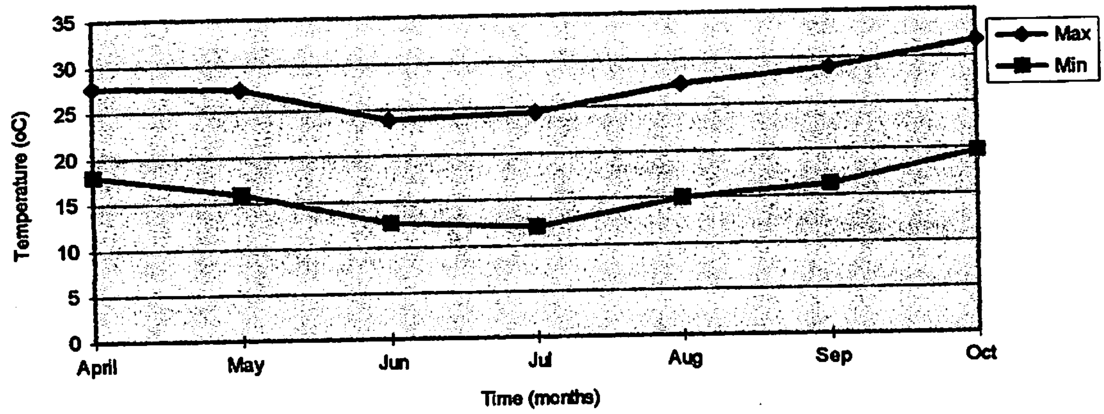

Figure 2a. Mean maximum and minimum water temperatures during fish culture period in tanks and pond 1995 growing season.

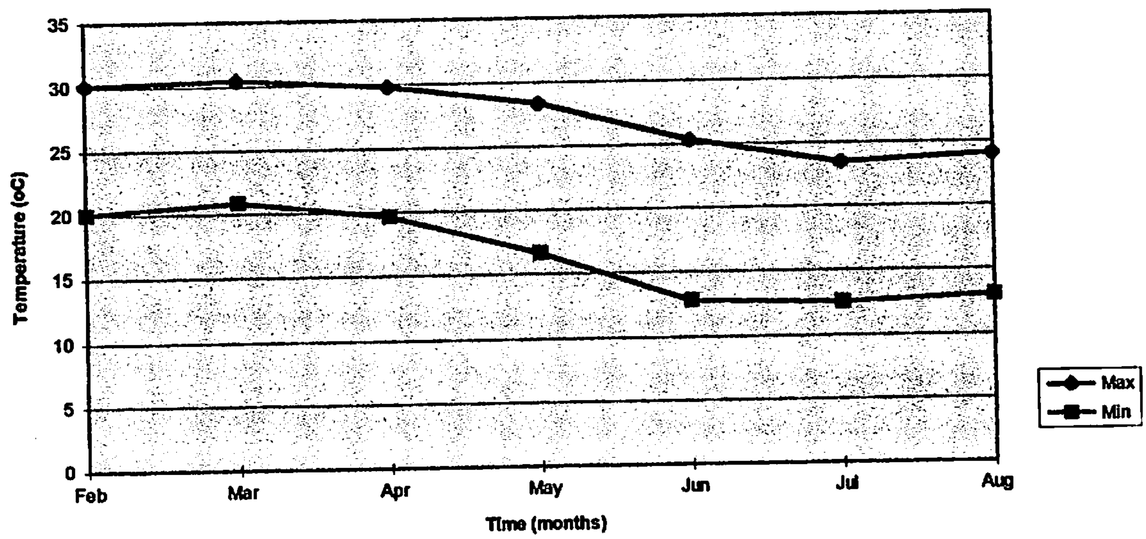

Figure 2b. Mean minimum and maximum temperatures during 1997 fish growing period in ponds.

Appendix 3

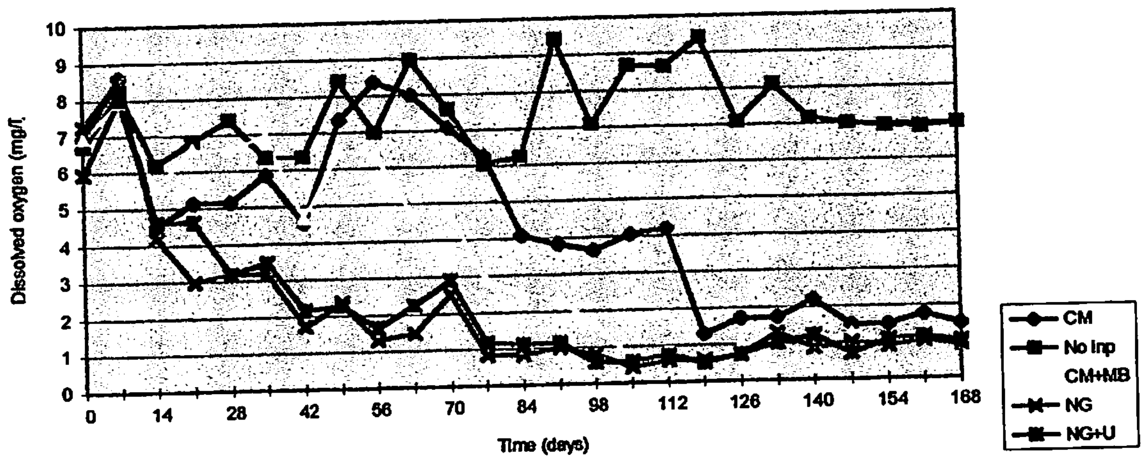

Figure 3. Effect of different chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG + urea, and no input on dissolved oxygen concentration in 200 m2 ponds stocked with *T. rendalli* and *O. shiranus* for 168 days.

Appendix 4

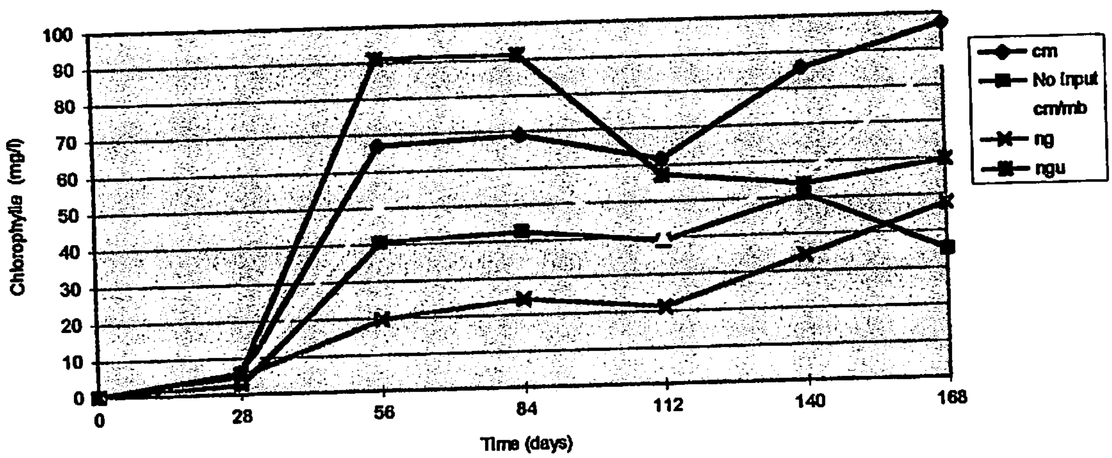

Figure 4a. Effect of chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG + urea, and no input on chlorophyll a concentrations in 200 m2 stocked with *T. rendalli* and *O. shiranus* for 168 days

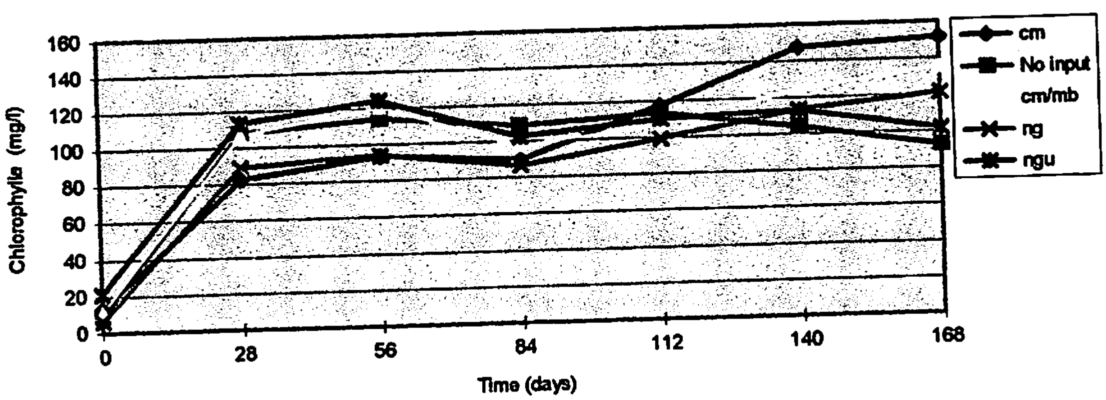

Figure 4b. Effect of chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG + urea, and no input in 5 m3 concrete tanks stocked with *T. rendalli* and *O. shiranus* for 168 days

Appendix 5

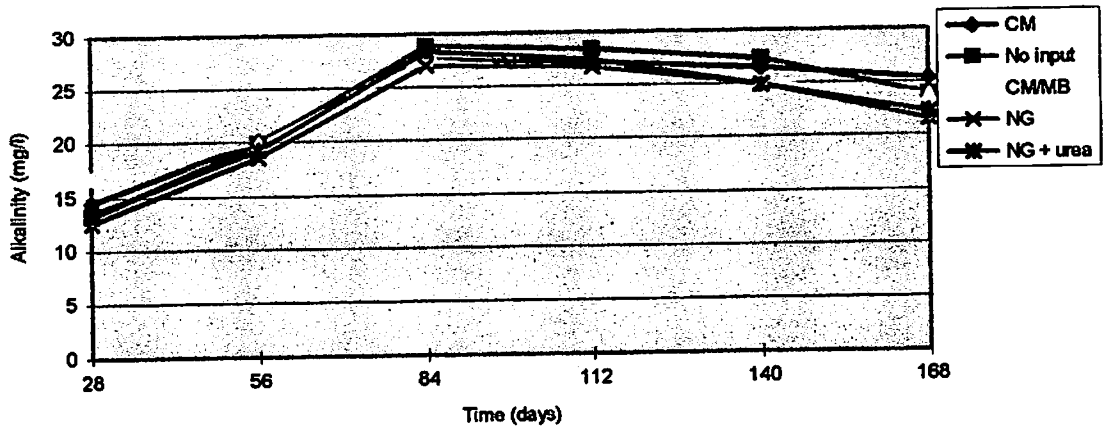

Figure 5a. Effect of chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG+ urea and no input on alkalinities in 200 m2 earthern ponds stocked with *T. rendalli* and *O shiranus* for 168 days.

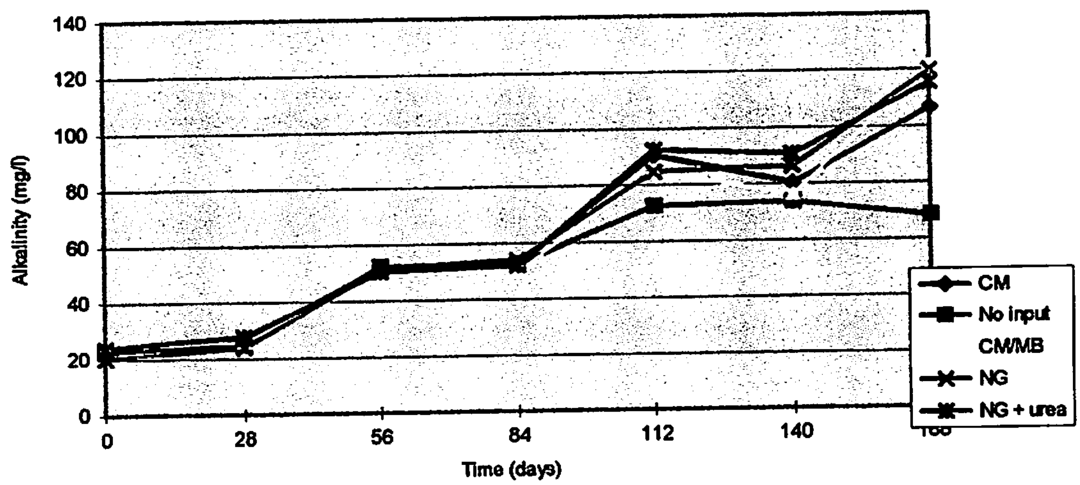

Figure 5b. Effect of chicken manure (CM), CM + maize bran (MB), napier grass (NG), NG + urea and no input on alkalinities in 5 m3 concrete tanks stocked with *T. rendalli* and *O . shiranus* for 168 days

Appendix 6

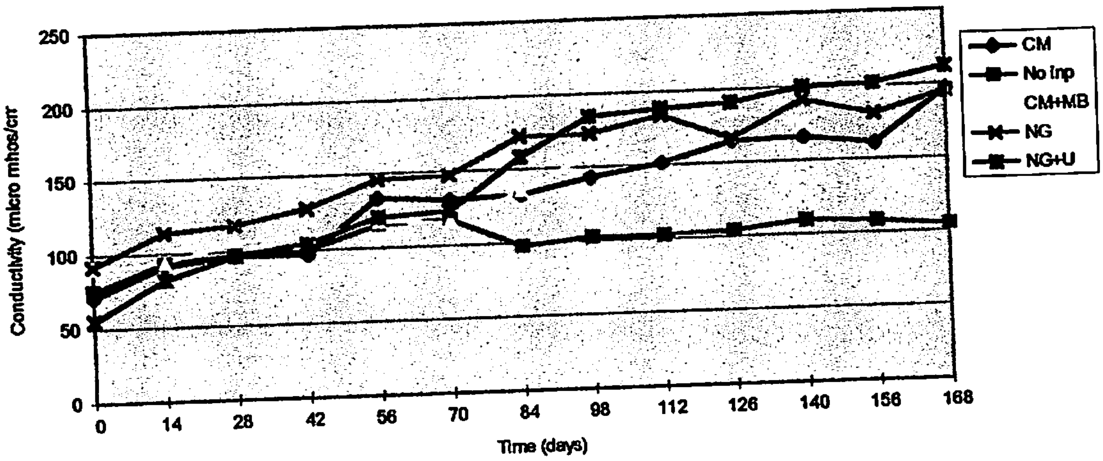

Figure 6. Effect of chicken manure (CM), CM + maize bran, napier grass (NG), NG + urea, and no input on conductivities in 5 m3 concrete tanks stocked with *T. rendalli* and *O. shiranus* for 168 days