PRODUCTION OF *TILAPIA RENDALLI* IN WEEDY PONDS RECEIVING NO EXTERNAL INPUTS

R. E. BRUMMETT
ICLARM/GTZ Africa Aquaculture Project
P. O. Box 229, Zomba, MALAŴI

ABSTRACT

Tilapia rendalli were stocked at a rate of one fish per square metre in six replicate 200 m^2 ponds and grown for 104 days. At stocking, three ponds were weed-free while three ponds had an average weed cover of 65.5%. The weed-free ponds received locally-available inputs at rates simulating those on local smallholdings. Weedy ponds received no inputs.

Water quality in the two treatments was similar except for significantly ($p < 0.5$) lower pH, higher electrical conductivity, and total dissolved solids in the weedless ponds. At harvest, fish stocked in weed-free ponds averaged 60.2 g (average standing stock = 707.29 kg/ha) while those in weedy ponds averaged 10.7 g (average standing stock = 91.25 kg/ha). Weed species composition changed toward more water-tolerant species, but percent coverage was unaffected by the presence of *T. rendalli*. Stomach content analysis taken at the end of the study found significantly ($p < 0.05$) more macrophytic material in fish from weedy ponds and more diatoms in fish from weed-free ponds. These findings may assist in developing fish cultural practices for smallholder farmers.

INTRODUCTION

Fish production in seasonal ponds is currently under investigation in the Southern Region of Malawi. As these ponds dry up during the hot season, semi-aquatic weeds grow in their still-moist bottoms. In the absence of expensive technology, removal of these weeds can be very labour intensive. At the same time, ponds with low productivity due to limited material input might benefit from leaving these materials in place. *Tilapia rendalli*, an indigenous species to Malawi, has been reported to feed on macrophytes (Caulton, 1976, 1977). This study was conducted to determine what labour-savings and input replacement/fertility enhancement could be achieved by stocking *T. rendalli* directly into unfed ponds containing macrophytic weeds left from a dry period.

MATERIALS AND METHODS

Six replicate 200m^2 ponds at the Malawi National Aquaculture Centre in Domasi were drained on 14 January 1993. All ponds were left dry, but in three ponds (Nos. 52, 53 and 58) the weeds were regularly removed, while the other three (Nos. 55, 56 and 59) were allowed to be naturally inhabited by weeds. After 63 days, weed specimens were collected and identified. Areas under weed coverage were estimated for each pond by extrapolation from 20, 1 m^2 quadrants.

On 18 March 1993, all ponds were flooded and stocked with 200 *T. rendalli* fingerlings averaging 4.6 g. Data collected on local farms was used to design mixed daily inputs of napier grass (*Pennisetum purpureum*), chicken manure, and maize bran (madeya) which were added to the weed-free ponds in quantities simulating those used by local smallholder fish farmers. No external inputs were added to the weedy ponds. Weeds rooted above the water line in all ponds were regularly cut to avoid creating snake refuges.

Water quality data were collected and averaged over 35 days to show trends. All measurements were made daily at 05:00 hrs. Dissolved oxygen, electrical conductivity, and pH were measured with a polarographic oxygen metre[1], an S-C-T metre[2], and pH metre[3] respectively. Temperature was also measured daily at 05:00 hrs and 22:00 hrs using the S-C-T metre. The two temperature readings were averaged into a daily temperature.

Chlorophyll *a*, total suspended solids, total alkalinity, and total dissolved solids were measured bi-weekly according to standard methods (APHA/AWWA/WPCF, 1989).

All ponds were harvested on 1 July 1993 after 104 days of fish growth. Stocked fish and fingerlings were separated, counted, and batch weighed. Adult fish were individually counted and fingerlings were sampled and an average weight calculated. Specific growth rates were calculated according to Hepher's (1980) equation:

$$SGR = \frac{3(W_t^{0.33} - W_0^{0.33})}{t - t_0} \tag{1}$$

Ten individuals (five adults and five fingerlings) from each pond were taken for stomach content examination. Stomach contents were pooled for each group (6 ponds x 2 size-classes = 12 groups), and a sub-sample taken for examination. Incidence of food organisms distinguished in three random passes at 40X through each mounted sample was recorded.

Immediately after draining the ponds, weed coverage and species composition were re-estimated by extrapolation from 20 x 1m ^{2} quadrants. Treatment variances and means

[1] Yellow Springs Instruments Model 51B

[2] Yellow Springs Instrument Model 33

[3] Hach Model 43800

were compared using ANOVA and Student's "T" (Zar, 1974).

RESULTS

Quantities of inputs to weedless ponds over the 14 week growth period of *Tilapia rendalli* are given in Table 1. Cumulatively each weedless pond received 64 kg Dry Matter (DM) of inputs - about 8.02 kg Nitrogen.

Table 1. Inputs to weedless ponds (52, 53, 58) over 14 weeks of *Tilapia rendalli* culture.

WEEK	Weekly Average Daily Inputs per 200m² Pond (kg)			Cumulative Input per Pond Over 14 Weeks (kg)		
	Wet Weight	Dry Matter	Nitrogen	Wet Weight	Dry matter	Nitrogen
1	0.61	0.012	0.004	0.61	0.26	0.02
2	2.71	0.005	0.043	12.06	3.97	1.11
3	2.20	0.005	0.017	32.34	12.79	2.24
4	1.67	0.004	0.010	47.90	20.15	2.85
5	1.46	0.004	0.014	56.86	24.99	3.35
6	0.95	0.003	0.009	61.70	27.58	3.82
7	1.48	0.006	0.013	68.91	31.19	4.03
8	1.16	0.004	0.012	78.48	36.27	4.66
9	1.65	0.004	0.016	92.84	43.64	5.55
10	0.61	0.002	0.006	99.38	47.19	5.98
11	0.64	0.002	0.007	105.12	50.42	6.37
12	0.77	0.002	0.009	111.94	54.75	6.88
13	0.74	0.002	0.009	118.60	59.00	7.37
14	1.14	0.003	0.012	128.48	64.45	8.02

Average daily temperature, dissolved oxygen measured at 5 AM, chlorophyll *a*, total suspended solids, and total alkalinity (Table 2) did not differ between treatments. Early morning pH was slightly lower, but not significantly, in the weedless ponds (mean 7.01) than in the weedy ponds (mean 7.26). Electrical conductivity and total dissolved solids were significantly ($p < 0.05$) higher in weedless (51.35 υmho cm^{-1} and 32.98 mg l^{-1} respectively) than in weedy ponds (31.39 υmho cm^{-1} and 17.83 mg l^{-1} respectively).

Table 2. Water quality data for weedy (55, 56, 59) and weedless (52, 53, 58) ponds.

Pond No	35-Day Interval	Average Temperature (°C)	5.00 AM Dissolved Oxygen (mg/l)	5.00 AM pH	Electrical Conductivity (μmho/cm)	Chlorophyll *a* (μg/l)	Total Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Total Alkalinity (mg/l)
Weedy									
55	19/3-22/4	25.6	3.62	7.16	30.39	7.93	2.77	16.0	11.60
	22/4-28/5	24.3	4.49	7.50	27.68	4.94	4.25	11.0	15.75
	29/5-01/7	23.7	4.67	7.19	31.55	1.72	0.81	17.0	18.40
Pond Average		24.5	4.26	7.28	29.87	4.86	2.61	14.7	15.25
56	19/3-22/4	25.6	3.46	7.08	31.18	7.82	7.50	18.0	12.10
	23/4-28/5	24.8	4.46	7.40	32.75	6.84	1.63	18.0	13.10
	29/5-01/7	23.4	4.95	7.11	50.20	6.52	3.29	23.0	22.60
Pond Average		24.6	4.29	7.20	38.04	7.06	4.14	19.7	15.93
59	19/3-22/4	25.3	3.48	7.27	31.50	6.33	12.38	20.0	10.35
	23/4-28/5	24.4	4.42	7.30	26.30	2.78	3.20	15.5	11.90
	29/5/01/7	23.3	4.90	7.30	20.10	2.60	3.50	22.0	13.10
Pond Average		24.3	4.27	7.29	25.97	3.90	6.36	19.2	11.78
Treatment Average		24.5a	4.27a	7.26a	31.29a	5.28a	4.37a	17.83a	14.32a
Treatment Variance		0.0128	0.002	0.0018	25.32	1.75	2.37	5.06	3.3

Pond No	35-Day Interval	Average Temperature (°C)	5.00 AM Dissolved Oxygen (mg/l)	5.00 AM pH	Electrical Conductivity (μmho/cm)	Chlorophyll *a* (μg/l)	Total Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Total Alkalinity (mg/l)
Weedless Ponds									
52	19/3-22/4	25.4	3.87	7.02	52.09	8.49	9.25	30.0	10.38
	23/4-28/5	24.1	4.07	7.17	54.51	9.67	3.81	22.0	17.60
	29/5-01/7	23.4	3.87	7.05	51.43	8.82	3.24	28.0	21.50
	Pond Average	24.3	3.94	7.08	52.68	8.99	5.43	26.7	16.49
53	19/3-22/4	25.8	3.16	6.95	45.61	8.16	5.88	35.0	17.30
	23/4-28/5	24.3	2.86	6.87	57.94	7.73	3.16	37.5	21.20
	28/5-01/7	23.5	2.32	7.05	51.64	15.21	4.11	39.0	21.50
	Pond Average	24.5	3.11	6.96	51.7	10.37	4.38	37.2	20.00
58	19/3-22/4	25.3	3.18	7.04	42.44	8.11	8.88	30.0	17.30
	23/4-28/5	24.4	2.84	6.91	53.36	6.47	6.63	34.3	16.23
	29/5-01/7	23.5	3.08	7.01	53.12	7.88	7.27	41.0	22.44
	Pond Average	24.4	3.03	6.99	49.64	7.49	7.59	35.1	18.66
Treatment Average		24.41a	3.36a	7.01b	51.35b	8.95a	5.80a	32.98b	18.38a
Treatment Variance		0.0091	0.1667	0.00276	1.61	1.38	1.79a	20.63	2.09

Treatment averages within columns with different associated letters are significantly different ($p < 0.05$)

Table 3. Average stocking weight, average harvest weight, average specific growth rate (SGR), weight of reproduction and standing stock data for *Tilapia rendalli* grown in weedless and weedy ponds.

Pond No.	Average Weight at Stocking (g)	Average Weight at Harvest (g)	Specific Growth Rate (g day^{-1})	Survival (%)	Weight of Reproduction (kg)	Average Weight of Fingerlings (g)	Standing Stock (kg ha^{-1})
Weedless							
52	4.9	57.2	0.061	89	3.9	2.49	704.08
53	4.2	56.8	0.063	81	4.2	1.61	670.08
58	4.7	66.6	0.067	92	2.7	2.56	747.72
Mean	4.6a	60.2a	0.064a	87.3a	3.6a	2.22a	707.29a
Weedy							
55	4.5	12.0	0.018	71	0.15	1.69	92.50
56	4.3	8.4	0.012	98	0.15	1.80	90.00
59	5.0	11.6	0.016	57	0.5	2.61	91.25
Mean	4.6a	10.7b	0.015b	75.3a	0.267b	2.03a	91.25b

Values within columns with different associated letters are significantly different ($p < 0.05$).

Fish growth and harvest data are shown in Table 3. *T. rendalli* grew significantly ($p < 0.05$) better in weedless (mean weight at harvest = 60.2 g) than in weedy ponds (mean = 10.7 g). Specific growth rates were significantly higher ($p < 0.05$) in weedless than in weedy ponds averaging 0.064 and 0.015 g day^{-1} respectively. Weight of reproduction was also greater ($p < 0.05$) in weedless (mean 3.6 kg $pond^{-1}$) than in weedy (mean 0.267 kg $pond^{-1}$). However, there were no differences in average weights of fingerlings between weedless (2.2 g) and weedy (2.0 g) ponds. Standing stock at harvest was significantly higher ($p < 0.05$) in weedless than in weedy ponds, averaging 707.29 kg ha^{-1} and 91.25 kg ha^{-1} respectively.

Frequency of food materials recorded from pooled stomach samples is shown in Table 4. The variability in stomach contents was quite high. For most types of food organisms, there were no significant differences between the frequency of ingestion among adults and juveniles, or between treatments. There was, however, a significantly ($p < 0.05$) greater density of macrophytic material and lower density of diatoms in stomachs of fish from weedy than weedless ponds. Adults in weedless ponds ingested fewer diatoms in relation to their size than did juveniles. In both weedy and weedless ponds, large quantities of sand were ingested. Although its amorphous nature made it difficult to enumerate precisely, large quantities of what was assumed to be maize bran (the main feed during the last days of the study) were found in the stomachs of fish from ponds receiving external inputs.

Table 5 illustrates the shift in species composition and percent weed coverage over the course of study. At flooding, weed cover over the weedy ponds averaged 65.5%. Of the weeds rooted in the pond bottoms, Gramineae provided most (80%) of the total pond cover of which 45.7% was contributed by *Paspalum cammersonii* and 34.4% by *Cynodon dactylon*. *Cyperus rotundus* (Cyperaceae) contributed only 8.7% of the total weed cover. Rooted in the banks but extending into the pond area were *Commelina africana* (Commelinaceae) and *Leersia hexandra* (Gramineae) which contributed approximately 6.7% and 4.7% of the total weed cover respectively. Scattered throughout the pond were individuals of *Ludwigia erecta, L. octovalvis* (both Onagraceae), *Amannia auriculata* (Lythraceae), and *Oryza sativa* (Gramineae).

At harvest, total weed coverage in the weedy ponds was not significantly different (66.3%) from that at flooding. The species composition of weeds rooted in the pond bottoms changed ($p < 0.05$) in favour of *Cyperus rotundus* (56.0% of total cover) at the expense of the various Gramineae species *Paspalum cammersonii* (7.7%), and *Cynodon dactylon* (6.7%). The bank rooted *Commelina africana* (15.7%), and *Leersia hexandra* (14.0%) did not significantly change with flooding or fish production. The individuals of *Ludwigia erecta, L. octovalvis, Amannia auriculata* and *Oryza sativa* grew, flowered and set seed over the course of the study.

Table 4. Incidence/frequency of food organisms identified in pooled *Tilapia rendalli* stomach samples (N=5) from weedy and weedless ponds.

Pond No.	Adult/ Juvenile	Diatoms	Other Phytoplankton	Micro-Crustacea	Other Zooplankton	Macrophytes	Zoo-benthos	Other
Weedy Ponds								
55	Adult	179/.73	33/.13	5/.02	2/.01	20/.08	6/.02	sponges, sand
	Juvenile	148/.74	35/.17	4/.02	0/0	13/.06	1/0	sand
56	Adult	126/.66	47/.24	6/.03	1/.01	12/.06	0/0	sand
	Juvenile	209/.89	16/.07	1/0	1/0	9/.04	0/0	sand
59	Adult	45/.56	22/.28	0/0	0/0	13/.16	0/0	fish, sand
	Juvenile	151/.73	40/.19	2/.01	2/.01	11/.05	1/0	sand
Adult Average		116.7a	34.0a	3.7a	1.0a	15.0a	2.0a	
Juvenile Average		169.3a	30.3a	2.3a	1.0a	11.0a	0.7a	
Treatment Average		143.0a	32.2	3.0a	1.0a	13.0a	1.3a	

Pond No.	Adult/ Juvenile	Diatoms	Other Phytoplankton	Micro-Crustacea	Other Zooplankton	Macrophytes	Zoo-benthos	Other
Weedless Ponds								
52	Adult	243/.80	56/.18	2/.01	0/0	3/.01	1/0	madeya, sand
	Juvenile	390/.86	51/.11	8/.02	1/0	2/0	0/0	madeya, sand
53	Adult	263/.86	41/.13	1/0	0/0	2/.01	0/0	madeya, sand
	Juvenile	373/.91	34/.08	2/0	1/0	1/0	0/0	madeya, sand
58	Adult	336/.89	37/.10	1/.02	0/0	4/.01	0/0	madeya, sand
	Juvenile	406/.89	47/.10	1/0	0/0	0/0	0/0	madeya, sand
Adult Average		280.7a	44.7a	1.3a	0.0a	3.0b	0.2a	
Juvenile Average		389.7b	44.0a	0.7a	0.7a	1.0b	0.0a	
Treatment Average		335.2b	44.3a	2.5a	0.3a	2.0b	0.1a	

Means within columns with different letters are significantly ($p < 0.05$) different

Table 5. Weed cover by species and total weed cover of weedy ponds before and after 104 days of *Tilapia rendalli* culture.

Before Fish Culture	Percentage of Total Weed Cover by Species & % pond cover by Weeds			
Pond Number	55	56	59	Average
Paspalum cammersonii	44	32	61	45.7a
Cynodon dactylon	36	39	28	34.3a
Cyperus rotundus	13	9	4	8.7a
Commelina africana	5	12	3	6.7a
Leersia hexandra	2	8	4	4.7a
Percentage of Pond Cover by weeds	67.0	59.5	70.0	65.5a
After Fish Culture	Percentage of Total Weed Cover by Species & % pond cover by Weeds			
Paspalum cammersonii	8	6	9	7.7b
Cynodon dactylon	4	9	7	6.7b
Cyperus rotundus	62	48	58	56.0b
Commelina africana	17	22	8	15.7a
Leersia hexandra	9	15	18	14.0a
Percentage of Pond Cover by weeds	59.5	73.5	66	66.3a

Averages within corresponding rows with different associated letters are significantly ($p < 0.05$)

In the weed free ponds, there was some growth into the pond water from the banks of *Commelina africana, Leersia hexandra* and *Cynodon dactylon* just at the waterline. At harvest, this multi-species growth covered 1.1%, 0.8% and 1.9% respectively the weedless ponds (mean coverage = 1.3%).

DISCUSSION

Acid soils at the National Aquaculture Centre and the consequent low total alkalinities in both treatments accounts for the generally low chlorophyll *a*, and total suspended solids concentrations. By limiting the availability of carbon for photosynthesis, total alkalinities of less than 20mg l^{-1} substantially restrict phytoplankton growth (Boyd, 1990). Although the fertility indicators were statistically similar due to high variabilities between ponds within treatments, the slightly lower dawn pH in the weedless ponds is probably due to the somewhat higher fertility of most ponds in that treatment. The greater amounts of electrolytes in solution indicated by the higher electrical conductivity and total dissolved solids readings in the weedless ponds may be the result of more active foraging in the bottom sediments by fish in these ponds. This would also explain the higher densities of diatoms in the stomachs of these fish. Conversely, the lack of weeds during the dry period in weedless ponds 52, 53 and 58 might have resulted in a greater percentage of oxidation of residual organic matter and a subsequently higher amount of material in solution.

The much greater growth rates and final average weights of fish in the weedless ponds illustrates the inadequacy of an exclusive diet of macrophytes for *T. rendalli*. The presence of large quantities of sand and diatoms in the stomachs of fish in both treatments illustrates the importance of benthic food organisms in the diet of *T. rendalli*. Even in the presence of abundant macrophytic material, this species needs a diversified diet to grow and reproduce well. The lower growth rates in the weedy ponds is probably due to access to the benthos having been restricted by higher densities of weeds.

Foraging in the bottom sediments, which the fish were undoubtedly doing, should have resulted in more zoobenthos in the stomachs. That so little was found may indicate that these organisms decompose rapidly in the low pH environment in the *T. rendalli* stomach (Caulton, 1976). The low frequency of benthos in the stomachs might also be due to the populations of these organisms having been substantially reduced earlier in the production period as generally occurs in channel catfish (*Ictalurus puntatus*), blue tilapia (*Oreochromis aureus*) and common carp (*Cyprinus carpio*) ponds (Miller, 1972).

In addition to a diversified diet of natural foods, the importance of pond inputs to *T. rendalli* growth cannot be over-looked. While macrophytic material is difficult to distinguish from the various colours, shapes and sizes of the pond inputs used in this study, that large amounts of this material had been directly ingested is certain. Inconsequential amounts of this amorphous material was identified in stomachs from weedy ponds. While the primary value of these inputs may be as fuel to the natural food chain (Schroeder *et al.*, 1990), the low degree to which they can be replaced by *in-situ* weeds has been clearly indicated by these findings.

As a species of importance in weed control, *T. rendalli* has some shortcomings. While the largely terrestrial grasses were significantly reduced by flooding and fish production, more resistant and hydrophillic species rapidly took their place. Unfortunately, aquatic weed problems are largely the result of infestation by this latter group of species rather than the softer, more palatable grasses which *T. rendalli* prefer (Chikafumbwa, *et al.*, 1991).

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