Observations on the effects of water exchange rate on the growth rate of *Oreochromis mossambicus* (Peters) Part 2: Juvenile fish over the first 60 days after hatching

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Abstract

Larvae were stocked at different densities in fibreglass tanks with 1 500 l capacity for a period of 60 d after hatching. Different water flow rates were used to establish the relationship between water used and growth (production) and the effect of different stocking densities on growth. A flow-through system to waste was used to prevent an accumulation of growth-limiting substances in the water.

A significant positive correlation of r=0.95 (p<0.001) between water exchange rate and growth rate was obtained with juvenile *Oreochromis mossambicus*. A positive correlation of r=0.82 (p=0.001) was also obtained between total water used per fish and the mean mass of the fingerlings at the end of the 60 d period.

An insignificant correlation of r=0.59 (p>0.05) was obtained between stocking density and water exchange rate.

Introduction

When the production studies were commenced in 1986 great difficulties were experienced to produce fair sized fingerlings over the first 60 d after hatching, which could be used in the production ponds. It was then noticed that a faster flow-through of water to waste enhanced growth. The aim was to produce fingerlings of about 20 g each over that period. The experiments were then designed to study this relationship between growth and water exchange and whether different stocking densities have any influence on this relationship. The only other information available on the growth of juvenile *O.mossambicus* was that of Henderson-Arzapola and Stickney (1983). They used a constant flow of 1.9 $\ell\cdot min^{-1}$ through tanks with 60 ℓ capacity and stocked at different densities.

Materials and methods

The experimental programme, carried out over a period of 4 years, was severely restricted by the lack of natural impounded water on the university campus and chlorinated tap water had to be dechlorinated in two reservoirs with a total capacity of 244 m^3 before use in the fish tanks. Replication of the treatments was therefore not always possible.

Circular fibreglass tanks of 2 m dia., 0.5 m depth and 1 500 ℓ capacity were installed inside a hothouse, converted into a hatchery. The required water depth was maintained by means of a vertical central overflow pipe. A screen prevented fish from escaping. Shade cloth (80%) placed over the tanks gave some shelter to the fish. The bottoms of the tanks were cleaned with a siphon twice daily. Details of the water flow rate ($\ell\cdot min^{-1}\cdot kg^{-1}$), depth, and stocking densities are summarised in Table 3. In the 1993 experiment Tanks J9 to J11 were stocked at different densities and the flow rate was calculated from the regression equation y=0.0058 x + 0.126 where y = flow rate ($\ell\cdot m^{-1}\cdot kg^{-1}$) and x = density ($fish\cdot m^{-3}$) as recommended by Visser and Iosifov (1995) for production fish.

The flow rate in Tank J12 was reduced to half of that of Tank J11 but the stocking densities in both tanks were the same (Table 3). The water was not recirculated to prevent an accummulation of unknown quantities of growth-limiting substances in the water. The tanks were artificially aerated by means of a blower to ensure an O_2 concentration above 5 $mg\cdot\ell^{-1}$. Thermostat controlled heaters were placed inside the tanks which kept the water temperature above the air temperature and reduced the temperature fluctuation to narrow limits (Table 2).

Fertilised eggs were removed from the female's mouth and incubated in 8 ℓ capacity glass funnels (1.3 m long) in which the water flow could be regulated. After hatching the larvae swam out through the upper outlet of the funnel into a 50 ℓ collecting tank with a very fine screen attached to its side-wall, preventing the larvae from escaping. From here they were transferred to a number of 60 ℓ tanks where they were kept for 5 to 7 d and feeding commenced about 4 d after hatching. The stronger larvae were then counted and transferred to the experimental tanks. Monosex male progeny were obtained by means of the sex reversal technique described by Guerrero (1975) and Hepher and Pruginin (1981). Commercial trout pellets (35% protein) were ground to a fine powder with an ordinary coffee-bean grinder. This grinder was very suitable as it prevented overheating of the powder and consequent destruction of the protein and vitamin contents of the feed. The maximum feed particle size fed to the larvae varied according to the size of the larvae and sieves with different mesh

TABLE 1
MAXIMUM FEED PARTICLE SIZE FED TO FISH AT DIFFERENT STAGES OF GROWTH

Fish mass (g)	Maximum particle size (mm)
Up to0.7	0.5
0.8 - 2.9	1
3 - 8	2
above 8	3

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TABLE 2
MEANS OF DISSOLVED O_2, WATER TEMPERATURE, pH AND UN-IONISED AMMONIA (NH_3) IN TANKS STOCKED WITH *O. MOSSAMBICUS*

Tank No.	8:00 Daily water temperature (°C)	O_2 ($mg \cdot \ell^{-1}$)	NH_3 (m mole$\cdot \ell^{-1}$)	pH
J1	28.8 26.0-30.0	6.6 5.8-7.2	0.003 Max=0.006	6.6 5.9-7.4
J2	27.8 25.0-30.0	6.8 6.0-7.5	0.001 Max=0.002	7.3 7.2-7.5
J3	29.4 26.7-31.4	6.0 5.2-6.3	<0.001 Max <0.001	5.9 5.7-6.2
J4	29.4 26.8-30.0	6.7 5.8-7.5	<0.001 Max <0.001	5.9 5.7-6.1
J5	28.3 25.0-31.0	6.6 5.0-7.3		
J6	28.4 26.0-32.0	6.0 5.2-6.8		6.9 6.5-7.2
J7	27.6 25.0-30.0	6.4 6.0-7.0		
J8	28.0 26.0-32.0	6.2 4.8-7.2		
J9	29.8 27.0-30.6	5.7 4.4-7.4	<0.001 Max<0.001	6.6 6.0-7.3
J10	30.1 29.0-31.0	5.3 4.5-6.6	<0.001 Max<0.001	6.6 6.1-7.3
J11	29.6 25.0-32.0	5.5 4.0-6.8	<0.001 Max=0.001	6.4 6.0-7.3
J12	29.9 29.5-31.0	5.7 4.5-7.5	<0.001 Max<0.001	6.5 5.8-7.4

TABLE 3
THE RELATIONSHIP BETWEEN PRODUCTION, WATER EXCHANGE RATE AND DENSITY OF JUVENILE *O. MOSSAMBICUS* OVER THE FIRST 60 d AFTER HATCHING

Season	Tank No	Tank capacity (ℓ)	Density (fish·tank^{-1})	Density (fish·m^{-3})	Mean mass (g)	Mean mass increase d^{-1} (g)	Production (kg.m^{-3})	Water flow (ℓ·min^{-1}·kg^{-1})	Total water used in tank (m^3)	Total water used in 1 m^3 (m^3)	Total water used per fish (m^3)	Water used to produce 1kg of fish (m^3)	Mortality (number)	Mortality (%)
1990	J1	800	250	313	21.2	0.35	6.64	3.7	416.9	521.1	1.67	78.5	22	8.8
	J2	800	250	313	13.2	0.22	4.13	3.8	339.3	424.1	1.36	102.7	12	4.8
1991	J3	500	167	334	24.0	0.40	7.70	4.0	342.2	684.4	2.05	88.9	6	3.6
	J4	500	500	1000	19.8	0.33	18.80	4.0	919.0	1835.0	1.84	97.8	25	5.0
1992	J5	1000	1000	1000	11.3	0.19	7.83	3.5	695.5	695.5	0.70	88.8	349	34.9
	J6	1000	1000	1000	11.1	0.19	10.81	3.5	1083.5	1083.5	1.08	100.2	30	3.0
	J7	1000	1000	1000	12.7	0.21	8.10	3.5	778.0	778.0	0.78	96.1	578	57.8
	J8	1000	1000	1000	11.2	0.19	8.45	3.5	999.3	999.3	1.00	118.3	295	29.5
1993	J9	1000	90	90	12.1	0.20	1.05	0.7	25.0	25.0	0.28	23.8	3	3.3
	J10	1000	330	300	15.6	0.26	5.09	2.0	257.4	257.4	0.78	50.6	4	1.2
	J11	1000	660	660	18.7	0.31	12.22	4.0	1167.0	1167.0	1.77	95.5	8	1.2
	J12	1000	660	660	14.6	0.24	9.53	2.0	482.3	482.3	0.73	50.6	5	0.8

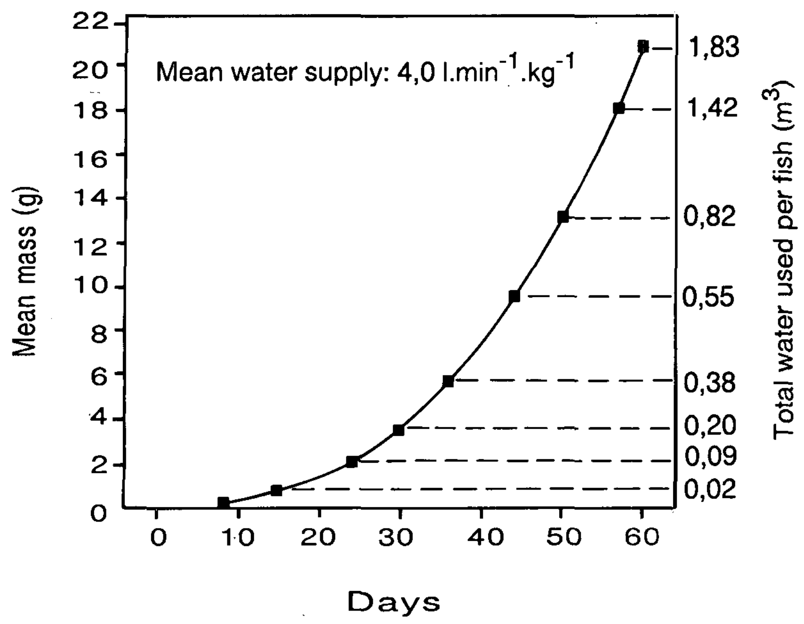

Figure 1
The growth rate of juvenile O. mossambicus *and the total water used per fish at different stages of growth*

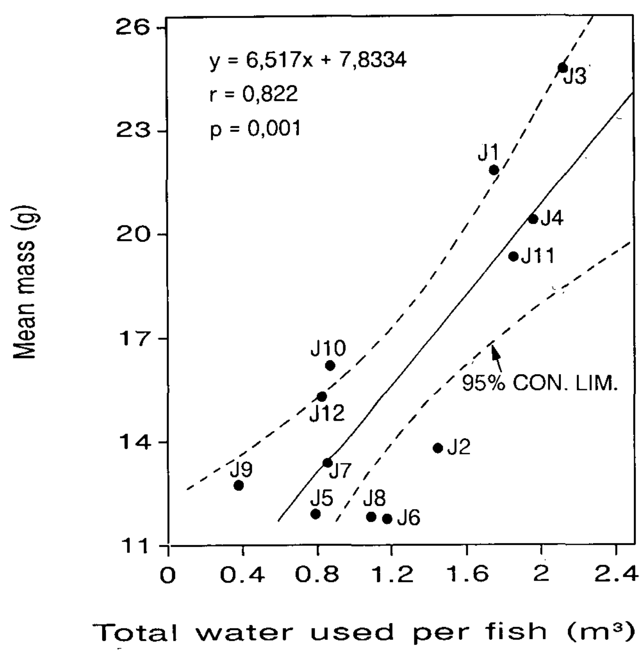

Figure 2
The relationship between growth rate and water used per fish over the first 60 d after hatching (Table 3)

sizes were used to facilitate this (Table 1).

One percent commercial trout multivitamin powder was added to the finely ground trout feed prior to feeding in all the tanks except Tanks J2 and J5 to J8 (Table 3). The daily amount of hormone treated feed, administered over the 60 d period was gradually reduced from 20% to 5% of body mass. Automatic feeders, operated by a timer, were used.

Fish samples were weighed at one week intervals in order to make adjustments to the predicted growth rate on which the calculations for daily food rations and water flow were based. Dead fish were also weighed and their mass was included in the production figures. Most of the mortalities, however, occurred during the first few days after transfer when they were still too small to be recovered for weighing.

Daily recordings were made of temperature (8:00), and weekly recording of pH (Orien meter, model 221), DO (YSI Oxygen analyser) and ammonia (Orion microprocessor ionanalyser) (Table 2). The incorrect ammonia readings of the faulty Orion microprocesser were ignored in the 1992 experiments (Tanks J5 to J8). Regression lines were drawn with a Statgraphics programme.

Results and discussion

With the flow rates used the toxic un-ionized ammonia (NH_3), pH and O_2 levels were kept within safe limits in all the tanks (Table 2) and should not have had any negative effect on the growth of the fish.

An acceptable growth rate was obtained when the water exchange rate was sufficient to remove all other growth-inhibiting substances from the tanks. If the means are calculated for Tanks J1 J3 J4 and J11, where acceptable growth was recorded, it appears that a mean mass of 20.9 g is attainable if a total of 1.83 m³ water

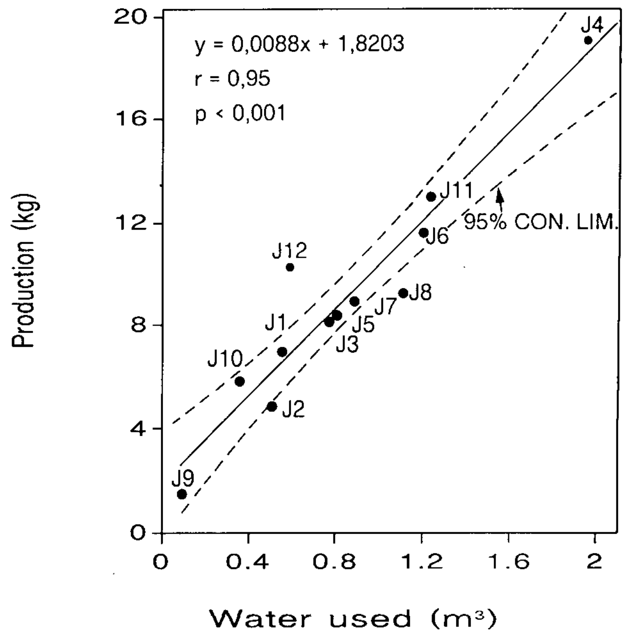

Figure 3
The relationship between water used and production per m³ of pond (Table 3)

per fish is circulated through the tanks over the 60 d period (Fig. 1 and Table 3). The water supply was 4.0 $\ell \cdot min^{-1} \cdot kg^{-1}$ to satisfy this total water requirement but it appears from Table 3 that the total water used per fish over the 60 d period is more critical for satisfactory growth. A significant correlation of r = 0.82 (p = 0.001) was obtained between total water used per fish and the mean mass of the fingerlings at the end of the 60 d period (Fig.2).

A positive correlation of r = 0.95 ($p<0.001$) was also obtained between water used and production (Fig 3). In contrast to the relationship described for adult *O. mossambicus* (Visser and Iosifov, 1995) a poor correlation of r = 0.59 ($p>0.05$) was observed between density and water used to produce 1 kg of fish (Fig. 4). Different stocking densities, up to 1 000 $fish \cdot m^{-3}$, therefore seem to have a very limited influence on the growth of juvenile fish up to a mean mass of about 20 g (biomass of 20 $g \cdot \ell^{-1}$) on condition that the total water used over the 60 d period is not less than 1.83 m^3 per fish as discribed above. This aspect however needs further investigation.

According to Henderson-Arzapolo and Stickney (1983) a hypersensitivity reaction, causing retarted grow and mortality, sets in at a biomass of about 20 $g \cdot \ell^{-1}$. At that biomass level their flow rate would be 1.6 $\ell \cdot min^{-1} \cdot kg^{-1}$ as they used a constant flow rate of 1.9 $\ell \cdot min^{-1}$ per 60 ℓ capacity tanks. This comparatively slow water flow rate and therefore the slow rate of removal of growth-limiting substances from the tanks have a bigger influence on the growth rate and mortality than biomass alone as suggested by them. It is not clear from their publication whether density played any significant role as a growth inhibitor as they used the same constant water flow of 1.9 $\ell \cdot min^{-1} \cdot tank^{-1}$ at all stocking densities.

The mean mortality of 3.9% in all the tanks except Tanks J5, J7 and J8 is normal but the high mortalities in the latter three tanks (Table 3) cannot be explained.

The lack of multivitamin additions to the feed retarted growth (Tanks J2 and J5 to J8 in Table 3). A mean growth of 13.2 g was obtained in Tank J2 in spite of a flow rate of 3.8 $\ell \cdot min^{-1} \cdot kg^{-1}$, compared with the mean mass of 21.2 g in Tank J1 where all other conditions were very similar except that multivitamins were added. The smaller total volume of water used per fish in Tank J2 (1.36 m^3) compared with Tank J1 (1.67 m^3) is due to the weekly adjustments to the water flow because of slower growth rate in Tank J2. Much more experimentation on feed composition and growth is, however, necessary.

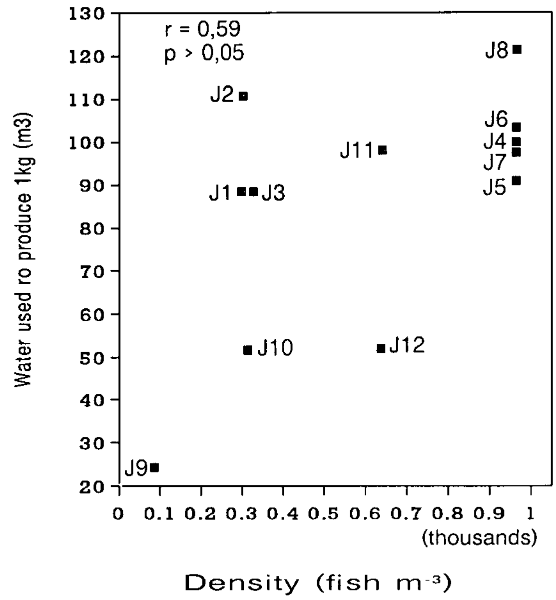

Figure 4
The relationship between density and water used to produce 1 kg of fish per m³ of pond

Conclusions

It is clear that maintaining acceptably low NH_3 levels by means of water exchange is not a guarantee that juvenile *O. mossambicus* will grow at a required rate. The removal of substances, which cause an auto-immune response as described by Henderson-Arzapolo and Stickney (1983), appears to play an important role in their growth.

A significant relationship existed between growth rate (production) and water exchange rate but high stocking densities do not have the same bearing on the water requirements to sustain acceptable growth as is the case with adult *O.mossambicus* (Visser and Iosifov, 1995). A water flow rate of 4 $\ell \cdot min^{-1} \cdot kg^{-1}$ and a total water supply of 1.83 m^3 per fish appear to be sufficient to ensure a mean mass of 20.9 g at all stocking densities, up to 1 000 fish·m^{-3}, at the end of the 60 d period.

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