Observations on fish growth in polyculture during late summer and autumn in fish ponds at the Umtata Dam Fish Research Centre, Transkei
Part II: The use of cattle manure with and without pelleted fish feed

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Abstract

Cattle manure, with and without pelleted fish feed, was used during the late summer and autumn periods of 1982 to evaluate the possible role of this manure in a fish polyculture production system. Results obtained show that the raw cattle manure from feedlot systems used directly in fish ponds may produce 1 t of fish per ha in less than 50 days. When supplementary feed is added with manure, approximately 2 t of fish can be produced within 98 days with a maximum yield of more than 2,5 t after 128 days. Indications are that digestion of the manure prior to application may further improve the fish production capacity of cattle manure. In comparison with pig manure, the cattle manure applied as fresh cow dung is inferior. Water temperatures falling below 15 °C may have contributed towards the comparatively poor performance of the cattle manure.

Introduction

This paper forms the second in a series of three on the use of various manures utilized in a fish polyculture production experiment carried out at the Umtata Dam Fish Research Centre. A detailed description of the fish species selected for the study, the pond conditions and of general pond management and climate of the area at the Umtata Dam Fish Research Centre, as well as of the materials and methods employed during the execution of the experiments is provided in Part I of this series. (Prinsloo and Schoonbee, 1984).

A considerable amount of information exists on the use of various kinds of manure in fish production, and particularly on the utilization of pig and chicken manure. (Woynarovich 1956, 1957; Tang, 1970; Bardach *et al.*, 1972; Buck *et al.*, 1979). In recent years much attention has been paid to the application of cattle manure in fish farming, especially to the use of liquid cow manure, as a waste product of the dairy industry. Excellent work in this field has been done in Israel (Schroeder and Hepher, 1976; Moav *et al.*, 1977; Rappaport *et al.*, 1977; Rappaport and Sarig, 1978; Wohlfarth, 1978; Wohlfarth and Schroeder, 1979; Wohlfarth *et al.*, 1980; Hepher and Pruginin, 1981). None of those studies made extensive use of fresh cattle dung as in the present study and in previous investigations in southern Africa (Schoonbee *et al.*, 1979; Cronje, 1981), where fresh manure was collected daily for application in a fish polyculture system.

The present investigation deals with the effects on growth of fish with cattle manure only and cattle manure in combination with pelleted fish feeds. The relative success of both is evaluated in order to determine the possible role of such locally available manure in polyculture fish production systems.

Collection and Application of Cattle Manure and Pelleted Fish Feeds

Fresh cattle manure was collected from a nearby feedlot kraal. Collections were made daily for five days per week during the early morning periods and transported in plastic containers to the ponds at the Umtata Dam Fish Research Centre. For application to the fish ponds, the specific quantities of manure required were first mixed with water and the resulting liquid was then dispersed over as much of the surface area of the ponds as possible. Routine dry mass determinations on the fresh cattle manure collected, showed the moisture content of the manure to fluctuate around 85%. This was used to calculate to dry mass of wet manure for each of the 28-30 day periods of the present study (see Tables 2 and 3).

During the initial stages of the study, cattle manure was applied daily for five days per week to ponds receiving cattle manure only (Table 2) in quantities equivalent to 4% of the total estimated biomass of the fish in each pond. This increased to 6 and 7% during the 3rd and 4th periods respectively (days 70-98), after which is was decreased to 3%, coinciding with the rapid drop in water temperatures in April and May. As was the case for the pig manure experiments (Prinsloo and Schoonbee, 1984), the volume of cattle manure was also increased to 5% during the last 32 day period, which lasted from 13 May to 13 June 1982 (Table 2), in order to establish the possible effects of the increased loads of manure on fish growth during the colder months of the year.

In the ponds where the application of cattle manure was supplemented with fish pellets (Table 3), the dosage quantities of fresh manure calculated as dry mass were kept constant at 4% of the total estimated biomass of the fish in these ponds for the first 50 days. This was then reduced to 3% until the 98th day and further reduced to 2% (Period 5) and, for reasons already men-

tioned, again increased to 5% during the last 32 day period (13 May-13 June). A 45% protein fish pellet was used, and applied at an initial daily ratio of 4% only from day 51 (3rd period) for 21 days after which the quantities were reduced to a daily application of 3% of the total estimated biomass calculated for each of these periods (45% protein trout pellets were used not only because of their lower price, but also because of the better binding properties which make it less water-soluble than the locally produced carp pellets). Difficulties in the collection of manure over weekends enabled the application of manure for only five days per week in contrast to pelleted fish feed which was applied for six days per week throughout the study period.

Results

Water chemistry of ponds

A summary of the results on the water chemistry of the two sets of ponds receiving cattle manure only and cattle manure plus pelleted fish feed, is presented in Table 1. Relatively more manure was added to ponds receiving cattle manure only, than to ponds receiving cattle manure and fish feed. This resulted in higher values, on the average, for parameters such as nitrate, ammonia and even phosphates (as may be expected) although the differences were relatively small.

Values for dissolved oxygen taken during the early morning hours of the days of sampling, were generally satisfactory with minimum values still exceeding 10%. On the average, the oxygen concentrations in both pond systems were reasonably satisfactory and although not recorded in Table 1, supersaturation conditions prevailed in most of these ponds later in the day.

Fish production in ponds

Survival rates of fish in the experimental pond-systems receiving cattle manure were not as good as those in which pig manure was used. No abnormal fish mortalities were observed during the course of the experiment and since these ponds were randomly distributed amongst the other experimental ponds, they were subject to the same probability of predation by waterbirds as those receiving pig and chicken manure. Investigations also showed that the ponds in which the best growth results for fish were obtained had the highest fish losses. Despite this fact, a survival rate of 80% and 69% was found for the ponds receiving cattle manure and cattle manure and fish pellets, respectively.

Although discussed in more detail in Part I (Prinsloo and Schoonbee, 1984) attention is again drawn to the rapid drop in water temperatures during the fifth and sixth periods of the investigation (12 April-13 June 1982).

Ponds receiving cattle manure

From the results in Table 2, it can be seen that approximately 73% of the actual yield, based on the maximum yield achieved during period five, had already been obtained after 42 days when the mean empirical standing crop of the fish for ponds receiving cattle manure only (Figure 1) stood at 1 021,7 kg/ha. This implies that in 86 days, only 332 kg/ha more was added to the total mean maximum yield of those ponds.

The decline in the standing crop at the end of the experiment (Period 6, Table 2) can be explained partly by the actual loss in mass of the fish as a result of the sharp decline in water temperature. The considerable reduction in the actual production of fish in kg $ha^{-1}d^{-1}$ also reflects the rapid diminishing in these values as from the third period, with a negative yield during the last (6th) period (Figure 1). This tendency occurred despite the fact that a substantial increase in the volume of cattle manure was made from the beginning of the third period (day 43). The MCR (manure conversion ratio), also reflects this phenomenon as it increases drastically from the third period (Table 2).

Ponds receiving cattle manure and pelleted fish feed

Judging by the standing crop for the consecutive periods of the study (Table 3), there was a consistent increase in the actual yields until, and including, the 4th period (15 March-11 April 1982). A decline in the production increments then occurred towards the fifth period with an eventual loss of approximately 61 kg/ha during the extended sixth period when a mean water temperature of 12,7 °C was recorded. The highest daily production was recorded during period 4 when 31,5 kg $ha^{-1}d^{-1}$ was obtained. The MCR was generally good, largely as a result of the addition of pelleted fish feed, which was supplied to the fish from 22 February 1982. Even though cattle manure was added to the ponds, the FCR (feed conversion ratio) was 1,5 only during the third period after which the FCR deteriorated to 2,7 (period 4) and 4,3 (period 5), respectively.

Individual contribution of the various fish species to the total production in ponds receiving cattle manure only and cattle manure and pellets, respectively

Results on the mean initial and final stocking densities expressed in numbers and biomass for the ponds receiving cattle manure only and cattle manure plus fish pellets, the total production in kg/ha, and the actual contribution of each species towards the final yield are represented in Table 4.

From Table 4 it is clear that the three common carp varieties, as well as silver carp, were the major contributors towards the total fish yields in ponds where cattle manure only was used. The black and grass carps which were stocked at relatively lower numbers clearly did not benefit as much as the other species from cattle manure as nutrient.

In the ponds where cattle manure and pelleted fish feed were applied, the three varieties of common carp clearly maintained their overall dominant position in the total yield obtained. These results also showed some improvement in the relative yields of black and grass carps. In contrast, the actual contribution of silver carp, being 188 kg/ha, did not differ much from its yield in ponds where cattle manure only was used. The possible negative influence of low water temperatures on the production of *O. mossambicus* in the ponds receiving cattle manure and pellets, is evident.

Discussion

Under natural conditions, water bodies contain proteins in the form of bacteria, benthic invertebrates, zoo- and phytoplankton. Such natural food also occurs in fish ponds and contains proteins, which expressed in dry weight, can have a value as high as 50%. (Schaeperclaus, 1963; Hepher and Chervinski, 1965; Hepher and Pruginin, 1981). Thus fish ponds under natural conditions may be able to support a certain biomass of fish, which can then sustain a natural growth without the addition of supplementary feed. If a certain point of fish biomass is reached, the available

TABLE 1
SUMMARY OF PHYSICAL AND CHEMICAL CONDITIONS IN FISH PONDS RECEIVING CATTLE MANURE ONLY AND CATTLE MANURE AND PELLETED FISH FEED

Analysis	N	$\bar{X}$	Range Min.	Range Max.	Sx	Cv
Ponds receiving cattle manure only						
Dissolved oxygen % saturation	57	40,80	17,0	70,0	12,48	30,56
pH	63		6,00	8,09		
Conductivity $\mu S/m$	60	167,70	98	231	40,43	24,10
Alkalinity as $CaCO_3$ mg/ℓ	59	16,8	5,0	40,0	8,06	47,99
Total hardness as $CaCO_3$ mg/ℓ	54	18,9	7,5	32,5	5,26	27,80
Nitrate (NO_3) mg/ℓ	53	0,25	0,004	0,415	0,10	38,50
Ammonia (NH_4) mg/ℓ	60	0,60	0,156	1,141	0,18	30,27
Orthophosphate (PO_4) mg/ℓ	57	0,27	0,035	0,488	0,09	34,76
Ponds receiving cattle manure and pellets						
Dissolved oxygen % saturation	55	34,20	13,0	62,0	13,83	40,47
pH	60		6,15	8,64		
Conductivity $\mu S/m$	60	221,60	125	310	48,31	21,80
Alkalinity as $CaCO_3$ mg/ℓ	57	43,4	12,5	82,5	21,59	49,81
Total hardness as $CaCO_3$ mg/ℓ	52	40,2	12,5	77,5	18,96	47,20
Nitrate (NO_3) mg/ℓ	50	0,12	0,005	0,269	0,07	58,33
Ammonia (NH_4) mg/ℓ	58	0,57	0,124	1,360	0,35	60,82
Orthophosphate (PO_4) mg/ℓ	55	0,23	0,056	0,460	0,14	61,63

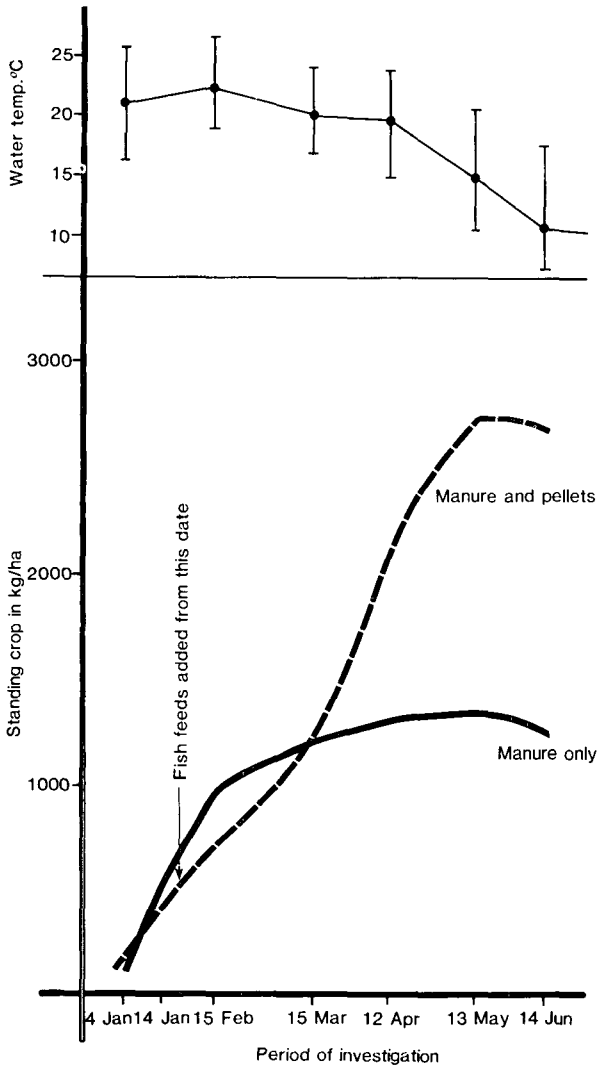

Figure 1A
Standing crop in kg/ha in ponds receiving cattle manure with and without pelleted fish feed

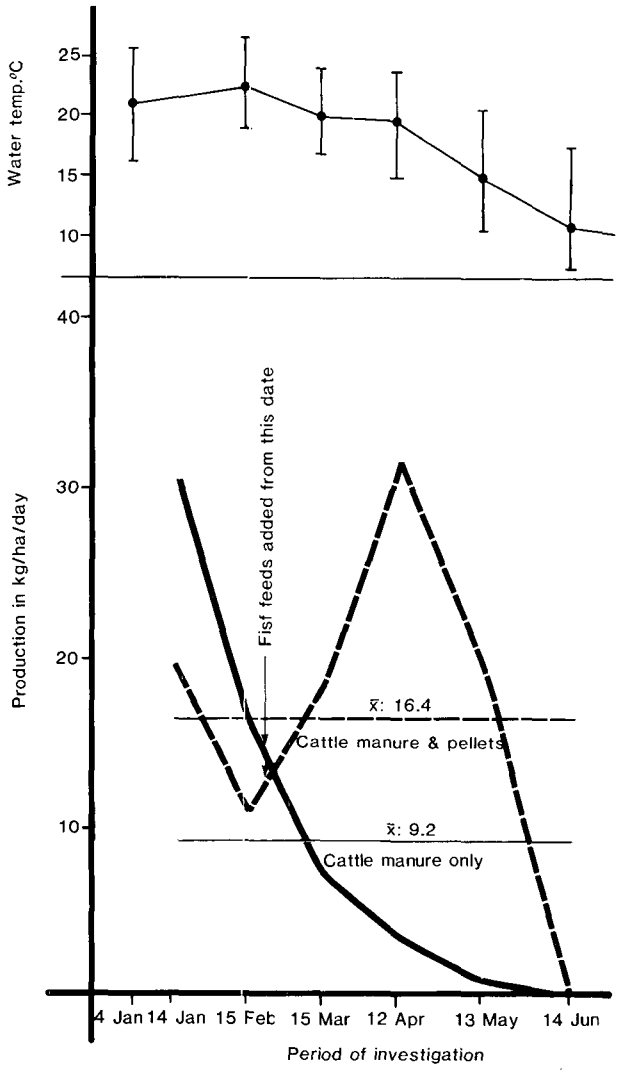

Figure 1B
Production in kg $ha^{-1} d^{-1}$ in ponds receiving cattle manure with and without pelleted fish feed

TABLE 2
RESULTS OBTAINED ON THE COMBINED MEAN GROWTH AND PRODUCTION OF THREE VARIETIES OF COMMON CARP, AND CHINESE BLACK, GRASS AND SILVER CARPS IN POLYCULTURE IN PONDS RECEIVING CATTLE MANURE ONLY, DURING THE PERIOD JANUARY TO JUNE, 1982 (160 DAYS)

Period					Estimated values based on initial numbers and biomass for each species			Empirical values based on final numbers and biomass for each species				
No.	Day(s)	Date	Mean and extreme pond temp. for period (°C)	Stocking (s) and final (f) densities of fish/ha	Standing crop in kg/ha	Yield increment in kg/ha	Production in kg $ha^{-1} d^{-1}$	Standing crop in kg/ha	Yield increment in kg/ha	Production in kg $ha^{-1} d^{-1}$	Manure dosage quantities in kg (as dry mass)	MCR (manure conversion ratio)
0	1	4/1		7 700(s)	139,2			139,2				
1	14	4/1-17/1	21,5 17,0-26,1		676,1	536,9	38,4	567,6	428,4	30,6	318,8	0,7
2	42	18/1-14/2	22,6 19,0-26,3		1 230,6	554,5	19,8	1 021,7	454,1	16,2	1 185,0	2,6
3	70	15/2-14/3	20,9 17,3-25,1		1 489,9	259,3	9,3	1 223,7	202,0	7,2	2 055,0	10,2
4	98	15/3-11/4	20,7 16,5-23,8		1 633,2	143,3	5,1	1 328,4	104,7	3,7	2 752,5	26,3
5	128	12/4-12/5	15,6 10,8-19,9		1 668,4	35,2	1,2	1 353,8	25,4	0,8	1 133,0	44,6
6	160	13/5-13/6	12,7 8,5-18,0	6 149(f)	1 536,7	−131,7	−4,1	1 247,5	106,3	−3,3	1 579,0	

protein might become a critical factor and in the absence of sufficient carbohydrates, natural protein required for growth will be utilized to make good the energy requirements of fish. At such a stage the shortage of protein becomes a growth-limiting factor (Müller and Merla, 1964). In order to sustain fish growth, organic wastes such as cattle manure can be added to the ponds, thereby providing directly and indirectly, through the food chain, additional protein which can become available to the fish. The manure particles can be ingested by some fish and the bacteria and protozoa attached to the particles, utilized (Schroeder and Hepher, 1976; Schroeder, 1978). Manure also adds to the dissolved nutrients in the pond-water, thus stimulating primary and secondary production and in this way increasing the available levels of protein in fish ponds. Added manure also has a limited ability to sustain optimal growth and to increase the yield of fish in a pond system. After a certain level of production is reached, and in order to promote active fish growth, balanced supplementary feeds must be added to meet the nutritional requirements of an active growing high density population of pond fish (Hepher, 1975).

In the present study, the growth-promoting ability of the cattle manure under existing environmental conditions declined sharply beyond yields of 1 000 kg/ha. In fact, 73% of the maximum yield recorded (13 May; Figure 1) had already been achieved within the first 42 days (15 February). Under normal conditions of pond management, this would have been the stage where supplementary feed in the form of fish pellets should have been added. Alternatively, a simple digester system could have been incorporated, whereby the protein contents of the manure can be increased substantially before application by means of microbial intervention, thus extending the protein utilization associated with the manure and further delaying the application of the high cost feed supplement in the form of fish pellets.

Where pelleted fish feeds was added in addition to manure (Figure 1), fish yields increased to approximately 2 700 kg/ha. Only the rapidly decreasing water temperatures (Table 3) appeared to interfere with the active growth of fish, so that a decline in production occurred in both pond systems (Figure 1, 14 June 1982).

When the actual yields of the ponds receiving cattle manure with and without fish pellets, are compared with the results obtained where pig manure was used with and without fish pellets (Prinsloo and Schoonbee, 1984), the superiority in the fish growth capacity of the pig manure over that of cattle manure used in its present form, is clearly demonstrated. In the case where manure alone was used, the total yield in kg/ha was approximately 0,25 t/ha higher for pig manure. Where supplementary feed was added, the difference was even greater with the pig manure plus pellets treatment yielding almost 1,4 t/ha more than was equivalent for cattle manure. It must, however, be borne in mind that the overall survival rate of fish in the ponds where cattle manure and pellets was used, was 60% compared to

TABLE 3

RESULTS OBTAINED ON THE COMBINED MEAN GROWTH AND PRODUCTION OF THREE VARIETIES OF COMMON CARP, AND CHINESE BLACK, GRASS AND SILVER CARPS AND *O MOSSAMBICUS* IN POLYCULTURE IN PONDS RECEIVING CATTLE MANURE AND PELLETED FISH FEED DURING THE PERIOD JANUARY TO JUNE, 1981 (160 DAYS)

Period					Estimated values based on initial numbers and biomass for each species			Empirical values based on final numbers and biomass for each species						
No.	Day(s)	Date	Mean and extreme pond temp. for period (°C)	Stocking (s) and final (f) densities of fish/ha	Standing crop in kg/ha	Yield increment in kg/ha	Production in kg $ha^{-1} d^{-1}$	Standing crop in kg/ha	Yield increment in kg/ha	Production in kg $ha^{-1} d^{-1}$	Manure dosage quantities in kg (as dry mass)	Fish pellets in kg	MCR* (manure conversion ratio)	FCR* (food convertion ratio)
0	1	4/1		9 400(s)	152,5			152,5						
1	14	4/1-17/1	21,5 17,0-26,1		610,4	457,9	32,7	429,7	277,2	19,8	318,7		1,1	
2	42	18/1-14/2	22,6 19,2-26,3		1 073,5	463,1	16,5	738,3	308,6	11,0	1 185,0		3,8	
3	70	15/2-14/3	20,9 17,3-25,1		1 847,0	773,5	27,6	1 259,6	521,3	18,6	1 062,5	805,0 as from 22/2	2,0	1,5
4	98	15/3-11/4	20,7 16,5-23,8		3 115,2	1 268,2	45,3	2 142,1	882,5	31,5	1 245,9	2 440,0	1,4	2,7
5	128	12/4-12/5	15,6 10,8-19,9		3 959,2	884,0	28,1	2 730,2	588,1	19,6	1 372,9	2 520,0	2,3	4,3
6	160	13/5-13/6	12,7 8,5-18,0	6 508(f)	3 886,1	−73,1	−2,3	2 669,5	−60,7	−1,9	1 613,1	2 776,6		

*Calculated as if manure or feed contributed exclusively to conversion ratio

TABLE 4

INDIVIDUAL CONTRIBUTION OF THE VARIOUS FISH SPECIES TO THE TOTAL PRODUCTION IN THE TWO SETS OF THREE PONDS EACH RECEIVING CATTLE MANURE ONLY AND CATTLE MANURE AND FISH PELLETS RESPECTIVELY

Fish Species	Stocking density and initial biomass per ha			Final density and biomass per ha		Fish yield in kg/ha	Percentage of total yield
	Numbers	Biomass (kg)	%	Numbers	Biomass (kg)		
Ponds receiving cattle manure only							
Aischgrund carp	1 600	51,2	26,6	1 317	255,5	204,3	19,4
Dor 70 carp	1 600	62,6	32,5	1 333	371,8	309,6	29,3
Aischgrund x Dor 70 carp	1 600	57,6	29,9	1 383	356,3	298,7	28,3
Black carp	600	14,1	7,3	583	38,3	24,2	2,3
Grass carp	600	4,1	2,1	283	28,5	24,4	2,3
Silver carp	1 700	3,1	1,6	1 250	197,1	194,0	18,4
TOTAL	7 700	192,7		6 149	1 247,9	1 055,2	100,0
Ponds receiving cattle manure and pellets							
Aischgrund carp	1 600	16,8	7,7	1 325	723,3	706,4	28,8
Dor 70 carp	1 600	47,8	22,0	1 075	746,7	698,9	28,5
Aischgrund x Dor 70 carp	1 600	51,7	23,8	983	711,9	660,3	26,9
Black carp	600	15,2	7,0	533	114,9	99,7	4,1
Grass carp	600	3,9	1,8	267	53,6	49,7	2,0
Silver carp	1 700	3,1	1,4	983	191,1	188,0	7,7
O. mossambicus	1 700	78,4	36,1	1 342	128,0	49,6	2,0
TOTAL	9 400	216,9		6 508	2 669,5	2 452,6	100,0

82% in the case of the pig manure and fish pellet ponds, which might have had a bearing on the overall yields of the former. As mentioned by Prinsloo and Schoonbee (1984), higher yields following the present system of polyculture with cattle manure and supplementary feeds can be achieved, provided the juveniles of the various fish species used in polyculture, are available for stocking at the outset of the summer season.

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