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

J.F. PRINSLOO
Department of Zoology, University of Transkei, Private Bag X5092, Umtata, 5100, Transkei

AND

H.J. SCHOONBEE
Research Unit for Fish Biology, Rand Afrikaans University, P.O. Box 524, Johannesburg, 2000

Abstract

Pig manure, with and without pelleted fish feeds, was employed during the late summer and autumn periods to evaluate its role in a polyculture fish production system in which the growth performance of varieties of the European common carp, the Chinese Black, Grass and Silver carps and the Tilapia *Oreochromis mossambicus* was established. Results obtained show that with careful pond management procedures, problems of oxygen depletion can be avoided even where large quantities of pig manure are applied daily. The results obtained also show that water temperature has an important bearing on the actual fish production capacity of pig manure, especially when it declines below 20 °C.

It is recommended that pig manure should not be applied to fish ponds when mean water temperatures decline below 15 °C. In the case where pelleted fish feeds supplemented the pig manure, the active growth of most fish was extended and a production of more than 40 kg $ha^{-1}d^{-1}$ was maintained even at mean water temperatures as low as 15,6 °C. During this period, and despite the rapidly declining water temperatures, a total production of almost 4 t/ha was obtained within 128 days. However, with a further decline in water temperature below 15 °C a considerable reduction in the actual fish production of the ponds took place. For that reason, it seems advisable to terminate pond production for the fish species used, when the mean water temperature declines below 15 °C.

Introduction

In most countries in Europe, and in Israel, where fish farming is being practised on a large scale today, fish production was originally based on a monoculture system using mainly the common carp *Cyprinus carpio* L. as pond fish (Reich, 1975; Wohlfarth, 1977; Halevy, 1979; Rappaport and Sarig, 1979). In contrast, the polyculture of pond fish has been practised for centuries in China, and in most of the Far Eastern countries fish polyculture has existed for more than a thousand years (Bardach *et al.*, 1972). Although monoculture of fish species such as the snake head and catfish is still practised in countries such as Hong Kong and the Republic of China (Chen, 1976; Sin and Cheng, 1977), the integration of pig and duck farming with fish production, whereby faeces of these animals are recycled through fish ponds, is an age-old practice amongst the Chinese.

Certainly the most important consideration in using polyculture in fish production is the better utilization of natural food present in the food web of a fish pond ecosystem. Typically aquatic weeds develop in a fish pond system which can then be utilized by cichlids such as *Tilapia zillii* (Val.)(Gervais), the Chinese grass carp *Ctenopharyngodon idella* (Val.) (Cross, 1969; Chen, 1976; Stott, 1979; Leventer, 1979, 1981; Kilambi, 1980; Mitchell, 1980; Shelton *et al.*, 1981) and *Tilapia rendalli* (Boulenger) (Le Roux, 1956; Jubb, 1967; Munro, 1967; Batchelor, 1978; Wager, 1968; Junor, 1969; Wager and Rowe-Rowe, 1972). Benthic macro-invertebrates are utilized by fish species including the European common carp *C. carpio* (Schoonbee, 1969; Chen, 1976; Hepher and Pruginin, 1981; Leventer, 1981; Zur, 1980). Detritus and phytoplankton are utilized by the grey mullet *Mugil cephalus* Linn. (Hepher and Pruginin, 1981; Leventer, 1981), *Oreochromis mossambicus* (Peters) (Chimits, 1955; Jubb, 1967; Bruton and Bolt, 1975; Bowen, 1981), *Oreochromis aureus* (Steindachner) (Leventer, 1981) and the Chinese silver carp *Hypophthalmichthys molitrix* (Val.) (Chen, 1976; Spataru, 1977; Stott and Buckley, 1978; Moskul, 1979; Leventer, 1979, 1981; Hepher and Pruginin, 1981). Athough species such as *O. aureus, T. zillii* and *T. rendalli* can utilize benthic filamentous algae, *Oreochromis galilaeus* (Artedi) is a much more specific feeder on algae (Leventer, 1981). The Chinese bighead carp *Aristichthys nobilis* (Richardson) is well known as a zooplankton feeder although it may also ingest phytoplankton and detritus (Chen, 1976; Stott and Buckley, 1978; Cremer and Smitherman, 1980; Hepher and Pruginin, 1981; Leventer, 1981). In ponds where molluscs such as *Lymnaea, Bulinus* and even the robust shelled *Melanoides* species establish themselves, the Chinese black carp *Mylopharyngodon piceus* (Richardson) can be included in a polyculture system to utilize this food component (Liu, 1955; Chen, 1976; Leventer, 1981). A predator which can control frogs and wild spawn of tilapia in fish ponds may be selected from *Clarias* or *Micropterus* species (Jubb, 1967; Leventer, 1979; Prinsloo *et al.*, 1981).

In view of the species mentioned and those which are used elsewhere in fish production, the following can be considered as the more suitable indigenous candidates for inclusion in fish polyculture under local conditions: *O. mossambicus*, *T. rendalli* and *C. gariepinus*. Of these, *O. mossambicus* and *T. rendalli* normally do not survive prolonged periods of water temperature below 10 °C, which make these species less suitable for large scale commercial production in most of the temperate regions in Southern Africa. In such areas, for these cichlids, the summer growing season is usually too short to allow sustained growth, and the marketing of these fish within one summer season after spawning. Because certain exotic species such as the Chinese and European carps have already proved, in commercial fish production systems elsewhere in the world, that they can survive cold winter temperature conditions and can also reach marketable sizes within one summer growing period, they were selected for the present series of polyculture experiments at the Umtata Dam Fish Research Centre.

Steadily increasing costs of the various components used to produce pelleted fish feeds, together with a worldwide shortage of fish meal, have forced the major freshwater fish-producing countries to give urgent attention to alternative means of supplementing the expensive pelleted fish feeds without sacrificing much actual growth performance of fish in ponds. One method is to promote the natural fishpond productivity and thus the carrying capacity of a pond. This can be done in several ways, for instance by using inorganic fertilizer to stimulate the primary pond productivity, which lies at the base of the food web. Pond production can be further improved by the application of organic substances such as chicken, cow or pig manure. This is a time-honoured method which was refined by the Chinese fish farmers many centuries ago (Hoffman, 1934; Lin, 1954; Tang, 1970), and its results approach the potential carrying capacity of a fish pond (Hickling, 1962) which according to Hepher (1967) is the maximum biomass of fish a pond can support. The fish-production potential of a pond can be further exploited by more efficient fishpond management procedures. For example, fish with different feeding habits can be introduced, in a combination likely to exploit as many as possible of the various trophic levels in ponds, and with a minimum of competition for food. In such a system of fish polyculture, care should be taken to maintain a balance in the numbers of each fish species used, so that over-utilization of a specific ecological niche does not occur.

Apart from the parameters just mentioned, climate, water quality, soil and other factors such as the naturally occuring African frog *Xenopus laevis* (Daudin) (Prinsloo *et al.*, 1981) which may influence the ecology of a fish pond system in a given area, are all important considerations affecting the eventual success, or lack of success in a polyculture fish production system.

In most of the freshwater-fish producing countries such as Israel and Taiwan, there are large areas where a prolonged summer season enables the fish farmer to spawn fish, raise the larvae and juveniles to stocking sizes and then grow the fish to marketable sizes during the same summer period. A country like Israel has the added advantage that it lies in a winter rainfall area with cloudless warm summer days creating warm pond water conditions exceeding 26 °C for prolonged periods. In South Africa, the Northern Transvaal, Northern Natal and coastal regions along the southern and eastern parts of the country are potentially suitable for the kind of fish culture in question. However, a country like Transkei, with a predominantly mild climate but with a relative abundance of good quality water, is not necessarily less suitable for fish production. In view of this a hatchery and experimental fish ponds were established at the Umtata Dam and a series of experiments were conducted to find suitable ways and means to overcome problems of pond fish production in an area with a short summer season, where average water temperatures exceed 20 °C only for approximately 5 months of the year.

In this paper which is the first in a series of three articles, the late summer season yields of different carp species and tilapia, using pelleted fish feed and pig manure, are discussed. The possible effects of declining early winter water temperatures during May and June on fish growth, are also considered.

Fish Species Selected for the Study

The fish species used in the present series of experiments are: the Dinkelsbühl variety of the Aishgrund common carp, *C. carpio*; the Israeli Dor 70 variety of the common carp, *C. carpio*; hybrids of the Aischgrund and Dor 70 varieties of the common carp; the Chinese silver carp, *H. molitrix*; the Chinese grass carp, *C. idella*; the Chinese black carp, *M. piceus*; and the cichlid, *O. mossambicus*.

The parent stock of the juveniles used in the present series of experiments was either imported from Marble Hall (Aischgrund variety of the common carp); from Dor (Israel) to Marble Hall (Transvaal) and to Tsolo (Transkei) (Dor 70 variety of the common carp); from Gan Shmeul (Israel) to Tsolo and Umtata (Transkei) (Chinese silver and black carps); or from Mindelaltheim Günsberg (West Germany) to Marble Hall and Transkei (Chinese grass carp). Some of the silver carp juveniles were originally taken to Tsolo in 1978 where they were raised in ponds using cattle manure (Schoonbee *et al.*, 1979).

Both the Chinese and European common carps used in the present study were spawned artificially at the Umtata Dam Fish Research Centre (Prinsloo and Schoonbee, 1983; Schoonbee and Prinsloo, 1984).

The Fish Ponds at the Umtata Dam Fish Research Centre

Thirty-two ponds with a total water surface area of 2,5 ha were constructed at the Umtata Dam Fish Research Centre. Piped water was obtained from the Mhlahlane river, approximately 50 km east of the site. This water is gravity-fed to the ponds and then further distributed to the ponds through a series of concrete canals. A total of nine 200 m² and nine 400 m² ponds were used during the present polyculture experiments which lasted from January to June 1982. All are earthen ponds and each is supplied with a monk overflow system. The mean depth of the ponds when full is 0,75 m. Overflow water is diverted by canals either into other ponds or it may be diverted to bypass the pond system.

The parent rock of the site where the ponds were constructed consists of Beaufort shales. These soils contain a very fine silt which remains suspended in the water for prolonged periods of time. This was particularly so after rains when initially there was no grass coverage in the area surrounding the ponds. The stocking of the different ponds with fish during 1981 (Cronje, 1981) prior to the present experiments, contributed much towards improvement of pond productivity during the present investigation.

After completion of the experiments by Cronje (1981) the ponds were emptied and the pond bottom allowed to dry out completely over the ensuing winter months of 1981. In contrast to the periodic application of agricultural lime to the ponds in 1981, agricultural lime was worked into the pond bottom in quantities of approximately 1 250 kg/ha prior to the filling of ponds with water. All ponds were constantly kept full by supplementing the water lost through seepage and evaporation.

Climatic Conditions

According to Koppen and Thorthwaite's classification (Schultze, 1947) the greater part of the Transkei has a sub-humid warm climate. Towards the east of the country as well as the coastal belt regions, conditions are sub-humid warm to humid warm in contrast to the Drakensberg highland region and adjacent areas in which the Umtata Dam Fish Research Centre is located, where cold winters with fairly frequent frosts and occasional snowfalls occur in the higher lying areas.

The annual precipitation in the region of the Umtata Dam Fish Research Centre usually fluctuates between 600-900 mm per year with maximum rainfall occurring in the period October to March. The driest months are in winter during June-July. The cloudy conditions which prevailed during the rainy season clearly affected water temperatures as well as optimal development of algal growths during the summer months.

Materials and Methods

Combination and stocking densities of fish species used

During the present experiment the stocking densities of fish in the 6 ponds used (see Table 4) varied between 7 700 and 9 400 fish per ha. The general availability of the three varieties of common carp used in the experiment made possible the execution of a multiple nursing method (Moav and Wohlfarth, 1968, 1973; Wohlfarth and Moav, 1972) which in turn permitted the evaluation of the inherent genetic growth potential of the different varieties under similar environmental conditions. A detailed analysis of the growth results furnished by this method for the three common carp varieties is given in a separate paper (Prinsloo and Schoonbee, 1984). As can be seen from Table 4 the mean values for the total density of the benthic feeding common carp varieties exceeded 50% of the fish stocked in each of the two sets of ponds used. Detritus and phytoplankton feeders, such as the silver carp and tilapia, *O. mossambicus*, were numerically subdominant, with the black and grass carps having very specific diets, being less numerous. In all these cases values were calculated for the estimated standing crop (kg/ha), biomass increment (kg/ha) and yields (kg $ha^{-1}d^{-1}$) assuming a hundred per cent survival. The empirical values for these parameters were based on the final densities of each variety (common carp) or fish species at the end of the investigation, when all the ponds were emptied.

Branding of fish

In order to distinguish between the three strains of common carp used, individual fish were branded using an apparatus similar to the one described by Moav *et al.*, (1960).

Feeding and manuring programme

The feeding and manuring programmes followed for each of the combinations of fish species used are listed in Table 4. Pelleted fish feed was obtained from Epol, East London. A 45% protein trout pellet, being less expensive than the 25 % protein carp pellet, was used (mass production of trout pellets resulted in cheaper production costs). Fresh pig manure with an average moisture content of 75% was obtained from the piggery of the local prison in Umtata. Daily collections were made for five days per week.

The daily dosages of wet pig manure expressed as dry mass, applied to ponds varied between 6-8% of the total estimated biomass of the fish during the first 98 days of the experiment. Due to the rapid decline in water temperatures as from mid April, the daily quantities of manure were reduced to 3% of the estimated fish biomass during that time. In order to ascertain the possible growth stimulating effects of pig manure on fish growth during cold water temperatures, the quantities of manure were increased to 5% (as dry mass) during an extended period of 32 days of the polyculture experiment when pond water temperatures averaged 12,7 °C, reaching a minimum of 8,5 °C.

In those ponds where manure and fish feed were applied together, the dosage quantities of manure were reduced to 3% (as dry mass of estimated fish biomass) during the first 90 days of the experiment. This was reduced to 2% during the period 12 April to 12 May and again increased to 5% during the extended colder period for the reasons already mentioned.

On the assumption that the natural carrying capacity of the ponds would be raised further with the application of pig manure and that sufficient food would be available to sustain optimal growth of the fish juveniles introduced into the ponds at the onset of the experiment, it was decided not to commence with the application of pelleted fish feed immediately. Pelleted fish feed for six days per week was provided only after 50 days from the onset of the experiment and in daily quantities of 4% of the estimated fish biomass. As from day 71 onwards the daily quantities of fish pellets were reduced to 3 % of the estimated biomass.

Application of inorganic fertilizers during the experiment

Ammonium sulphate as well as superphosphate were applied fortnightly to all the ponds in quantities of approximately 70 and 60 kg/ha, respectively. Depending on the water chemistry of the ponds, these quantities were manipulated upwards or downwards at times. In order to compensate for low pH values and to increase the hardness of the pond water slightly, agricultural lime was also periodically added when necessary.

Physical and chemical analysis

Water temperatures in the ponds were recorded on an installed Thies hydro-thermograph supplied with a seven-day recorder. Dissolved oxygen values of the water in the ponds were taken with a Metrohm O_2 Meter Model 627 whilst pH values were measured with a portable Metrohm Meter Model E604, recording to the nearest 0,01 reading. Electrical conductivity was measured with a Metrohm Conductivity Meter Model E587. Chemical parameters were determined according to the APHA Standard Methods for the Examination of Water and Wastewater (1971). Analysis included:

Total alkalinity	–	as $CaCO_3$ in mg/ℓ
Calcium hardness	–	as $CaCO_3$ in mg/ℓ
Total hardness	–	as $CaCO_3$ in mg/ℓ
Ammonia nitrogen	–	Nessler's method in mg/ℓ
Nitrate nitrogen	–	Cadmium reduction method in mg/ℓ
Orthophosphate	–	ascorbic acid method – PO_4 in mg/ℓ

Length and mass determination of fish

At the end of each period an approximate 20% representative sample of each fish species used in each pond was caught with a seine net. Fork and total lengths were measured on a standard measuring board, measuring accurately to 0,1 cm while the mass of each fish was determined on an electronic balance, weighing accurately to 0,1 g.

Discussion of Results

Water temperatures

Pond water temperatures recorded during 1980-1981 showed that on average the mean water temperature declined below 20 °C between April and October. The coldest months of the year were June, July and August, with the lowest mean of 8 °C recorded in July. The warmest months were from November to February when maximum temperatures of the water exceeded 25 °C. Mean water temperatures were below 15 °C from June (winter) to the first half of October (spring). As in the previous year the mean water temperatures during the months of January, February and March were above 20 °C. A rapid decline in water temperatures occurred during the first half of April with minimum values obtained being less than 11 °C. Mean water temperatures stabilized around 15 °C during the period mid-April to mid-May. A further decline from 15 to 10 °C in the mean water temperatures then followed towards June.

Data for the past three years on water temperatures at the Umtata Dam Fish Research Centre, revealed that for five months of the year the mean water temperatures actually exceeded 20 °C, and can therefore be considered as suitable for the active growing of warmwater fish.

Water chemistry of the ponds receiving pig manure only

A summary of the physical and chemical analysis done on ponds receiving pig manure only is given in Table 1.

Relatively low dissolved oxygen levels were obtained. It must be borne in mind that measurements were made during the early mornings when the oxygen concentration in fish ponds was normally at its lowest. Even so a mean saturation level of 35% with a minimum of 15% pointed towards the danger of oxygen depletion in ponds receiving pig manure. Fluctuations in pH could however mainly be ascribed to the effect of algal activity.

Values for conductivity, alkalinity and total hardness suggested a mild mineralization of the water which was ascribed partly to seepage but also to the periodic application of lime and manure.

Values obtained for nitrate, ammonia and phosphate, suggested that these ponds maintained reasonable growths of algae without the danger of the depletion of any of these nurients in the water.

Water chemistry of the ponds receiving pig manure and pellets

There is very little difference in the general water chemistry of ponds receiving only manure and those receiving fish pellets and manure (Table 1). The reduction in the quantity of the manure applied is, however, reflected in the nutrient loads, which were generally higher in the ponds receiving pig manure alone. Oxygen values were slightly higher in the ponds receiving manure and pellets.

Fish production in ponds receiving pig manure only

From Table 2 it is clear that there were factors affecting the optimal survival of fish in these ponds. Only 79% of the fish initially stocked remained after a period of 160 days.

Investigations by research workers such as Schoonbee *et al.*, (1979) and Prinsloo *et al.*, (1981) show that the African frog *X. laevis* poses a serious threat to fish culture in Transkei and the juveniles of most of the carp species used in fish culture are being preyed on by this frog. However, the loss of specimens of the common carp varieties, the grass carp and the black carp, which were too big for predation by *Xenopus*, suggests there is also

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

Analysis	N	$\bar{X}$	Range Min.	Range Max.	Sx	CV
Ponds receiving pig manure only						
Dissolved oxygen % saturation	56	35,4	15	67	13,45	38,0
pH	63		6,34	8,40		
Conductivity µS/m	60	186	110	340	48,46	26,1
Alkalinity as $CaCO_3$ mg/ℓ	57	30,1	10,0	65,0	11,78	39,1
Total hardness as $CaCO_3$ mg/ℓ	52	29,1	12,5	55,0	9,83	33,8
Nitrate (NO_3) mg/ℓ	50	0,240	0,015	1,151	0,19	79,2
Ammonia (NH_4) mg/ℓ	58	0,620	0,100	1,243	0,24	39,1
Orthophosphate (PO_4) mg/ℓ	55	0,105	0,105	0,939	0,18	46,5
Ponds receiving pig manure and pellets						
Dissolved oxygen % saturation	59	37,4	16	74,0	14,27	37,9
pH	63		6,20	8,18		
Conductivity µS/m	60	194	115	325	44,57	22,9
Alkalinity as $CaCO_3$ mg/ℓ	59	28,8	10,0	70,0	16,62	57,7
Total hardness as $CaCO_3$ mg/ℓ	53	25,3	12,5	50,0	10,57	41,3
Nitrate (NO_3) mg/ℓ	52	0,130	0,012	0,328	0,06	46,7
Ammonia (NH_4) mg/ℓ	59	0,440	0,013	0,902	0,21	47,1
Orthophosphate (PO_4) mg/ℓ	56	0,260	0,078	0,583	0,16	61,3

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 PIG 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)	147,8			147,8				
1	14	4/1-17/1	21,5 17,0-26,1		557,0	409,2	29,2	357,6	209,8	15,0	531,3	2,5
2	42	18/1-14/2	22,6 19,0-26,3		1 012,5	455,5	16,3	809,7	452,1	16,1	2 062,5	4,6
3	70	15/2-14/3	20,9 17,3-25,1		1 434,2	421,7	15,1	1 148,2	338,5	12,1	2 191,7	6,5
4	98	15/3-11/4	20,7 16,5-23,8		1 709,2	275,0	9,8	1 372,2	224,0	8,0	2 833,3	12,6
5	128	12/4-12/5	15,6 10,8-19,9		1 796,6	87,4	2,9	1 439,2	67,0	2,2	1 191,7	17,8
6	160	13/5-13/6	12,7 8,5-18,0	6 067(f)	1 819,4	22,8	0,7	1 459,2	20,0	0,6	1 814,8	90,7

predation by fish-eating waterbirds (Du Plessis, 1957; Junor, 1972) such as the white-breasted cormorant *Phalacrocorax carbo* (Linn.) which frequently attempted to visit the ponds guarded during the day. The reed cormorant *Phalacrocorax africanus* (Gmelin) was also occasionally observed at the ponds. Kingfishers seldom created problems but the grey heron *Ardea cinerea* (Linn.) damaged fish extensively, expecially during the evenings when the ponds were not guarded. Juveniles of the grass carp may also have been eaten by the hammerhead *Scopus umbretta* (Gmelin) which frequents the ponds.

From Table 2 and Figure 1 it can be observed that the mean water temperatures decreased to be low 20°C as early as the first week in April. It is also clear that there is a marked decline in the daily fish production capacity in the ponds when water temperatures fall below 20°C, with almost no growth of any of the fish species in the period mid-May to mid-June. Despite the fact that in more than 39% of the period of investigation water temperatures averaged 15,6 °C and less (Table 2) and that the yield during this particular time was limited to only 87 kg/ha, i.e. 6% of the total yield, almost 1,5 t of fish could still be produced per hectare. The major disadvantage of such late production was that most fish, because of the relatively small size of the fish originally stocked at the beginning of the experiment, were not yet of marketable sizes. In consequence, fish had to be overwintered before active growth could again commence.

The negative effect largely exercised by declining water temperatures on fish production is also exemplified by the feed conversion factor as expressed by the quantities of manure used in the production of fish. For instance, during the first 14 days cycle when sufficient natural food was still available in the ponds, only 2,5 kg of manure (dry mass) was required to produce 1 kg of fish. Values of 4,6 and 6,5 for the manure conversion ratio (MCR) must be considered as very favourable for pond water where temperatures barely exceed 20 °C on average. The effects of the declining water temperatures on the manure feed conversion ratio was already felt between the 70th and 98th day period of the experiment when more than 12 kg of (dry) manure was required to produce 1 kg of fish. This increased to almost 18 kg for the period 98 to 120 days. To illustrate the severity of cold water conditions of fish yields, an extended period was included – Period 6 – (days 128-160) where the addition of 90 kg of pig manure could only produce 1 kg of fish. When mean temperatures dropped below 15 °C, there is the danger when large quantities of manure are added, of ensuing anoxic conditions, because nutrients from organic material are less efficiently incorporated into the food web at such low temperatures.

Fish production in ponds receiving pig manure and fish pellets

The effect on the production rate of pelleted fish feed when applied together with manure can clearly be seen in Table 3 and Figure 1. More than 4 t of fish were produced over the same period and furthermore a total production of 40,8 kg $ha^{-1}d^{-1}$ was still maintained during the period when the mean water

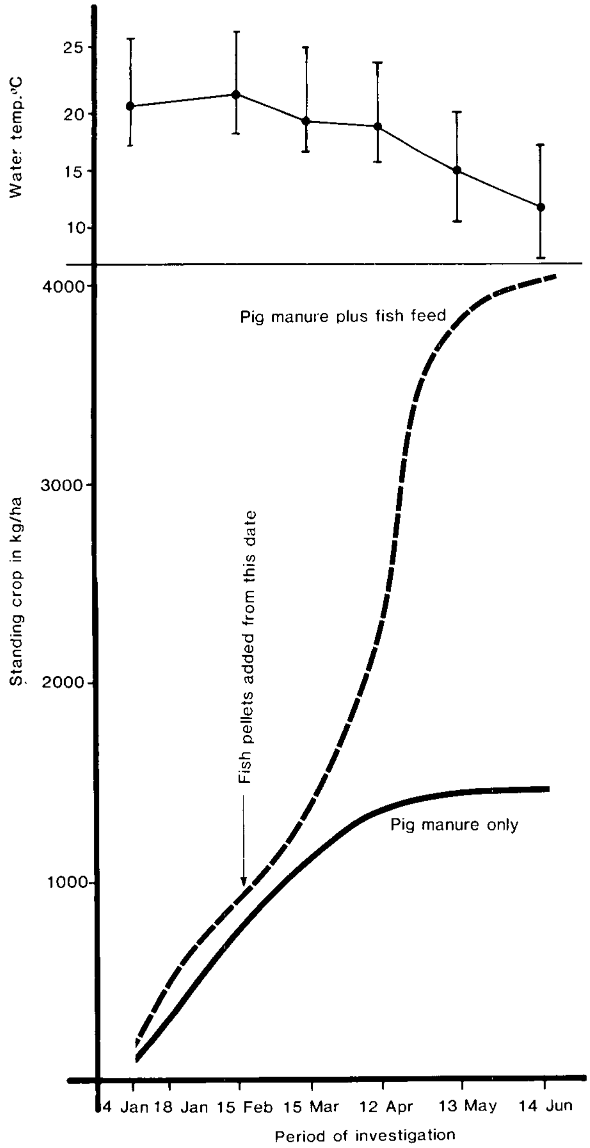

Figure 1A

Standing crop in kg/ha in ponds receiving pig manure with and without pelleted fish feed

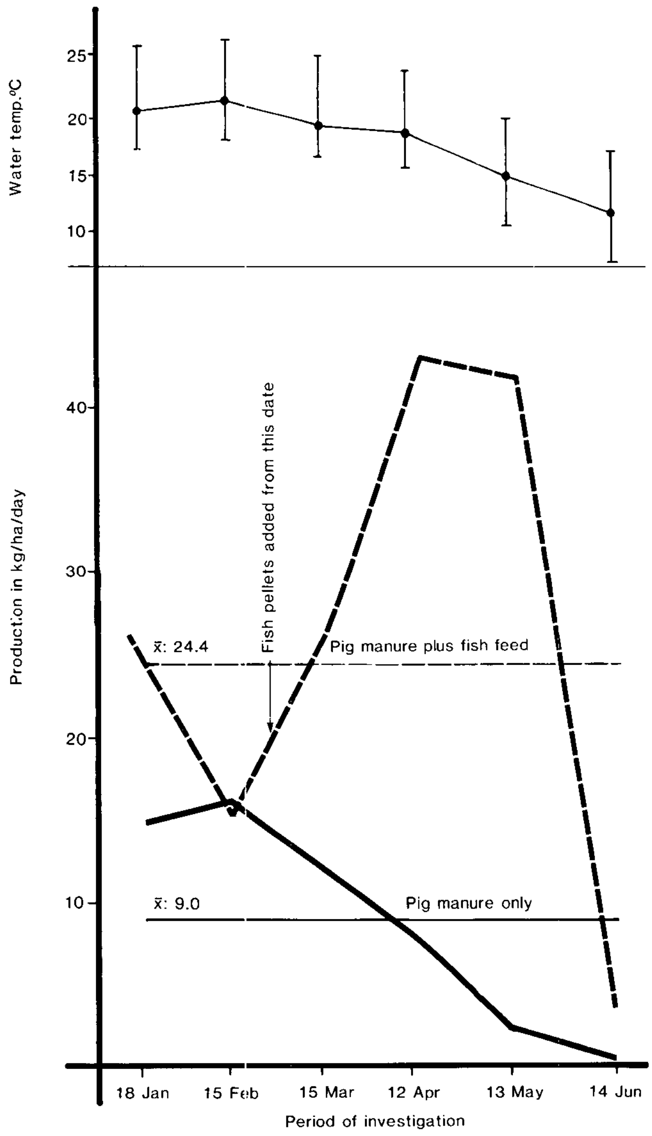

Figure 1B

Production in kg $ha^{-1} d^{-1}$ in ponds receiving pig manure with and without pelleted fish feeds for the period January-June 1982

temperatures averaged 15,6 °C. Much of this yield was contributed by the three common carp varieties used in the experiment. It was only during the extended 6th period that the daily production declined to 3,7 kg/ha. In this case, the operation should have been terminated at the end of the 5th cycle, i.e. after 128 days.

When manure alone was used (4 January-21 February) the MCR of 1,6 during the first 14 days was again extremely favourable, for reasons already explained earlier in the discussions. Even an MCR of 5,2 during the 2nd (28 day) period must be considered good. The reduction of the MCR to below 2 during the 3rd to 5th periods can largely be ascribed to the application of fish feeds which showed a feed conversion ratio (FCR) for the 43rd to 70th day period of only 1,3. Here again the contribution of the manure cannot be ignored. Despite the addition of manure during the 4th and 5th periods and even though a production of more than 40 kg $ha^{-1}d^{-1}$ could be maintained, the FCR based on the quantity of the pelleted feed used during this time, increased to more than 2. How much the decreasing water temperatures contributed towards this phenomenon is uncertain, but when the mean water temperatures reached 12,7 °C during the extended period of study, the pelleted fish feed was almost completely wasted and only 117 kg of fish per ha could be added to the total production of 4 046 kg over the last 32 days.

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

In Table 4 a breakdown is given of the final fish yields in the two sets of ponds where pig manure and pig manure and pellets, respectively, were used. In both pond systems the three common carp varieties contributed largely towards the total yields obtained. This is especially so when pelleted fish feed was added to the ponds.

In the ponds where the manure alone was used, the Chinese silver carp made a substantial contribution by adding almost 17% to the total production of fish. This contribution by silver carp may however be the result of the high stocking density (1 700 per ha) coupled with the presence of detritus and phytoplankton in

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 PIG 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)	199,1			199,1						
1	14	4/1-17/1	21,5 17,0-26,1		622,1	423,0	30,2	537,1	338,2	24,2	531,3		1,6	
2	42	18/1-14/2	22,6 19,2-26,3		1 096,4	474,3	16,9	931,1	394,0	14,1	2 062,6		5,2	
3	70	15/2-14/3	20,9 17,3-25,1		1 934,8	838,4	29,9	1 539,0	607,9	21,7	1 077,1	764,2 as from 22/2	1,8	1,3
4	98	15/3-11/4	20,7 16,5-23,8		3 195,8	1 261,0	45,0	2 706,2	1 167,2	41,7	1 282,5	2 527,5	1,1	2,2
5	128	12/4-12/5	15,6 10,8-19,9		4 576,1	1 380,3	46,0	3 929,4	1 223,2	40,8	1 430,0	2 565,0	1,2	12,1
6	160	13/5-13/6	12,7 8,5-18,0	7 739(f)	4 711,9	144,8	4,5	4 046,6	117,2	3,7	1 700,8	3 060,0	12,2	26,1

*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 PIG MANURE ONLY AND PIG 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 pig manure only			%				
Aischgrund carp	1 600	23,2	15,7	1 225	308,0	284,8	21,7
Dor 70 carp	1 600	51,8	35,0	1 342	404,4	352,6	26,9
Aischgrund x Dor 70 carp	1 600	52,6	35,6	1 375	436,6	384,0	29,3
Black carp	600	13,0	8,8	533	49,2	36,2	2,9
Grass carp	600	4,1	2,8	267	38,8	34,6	2,6
Silver carp	1 700	3,1	2,1	1 325	222,2	219,1	16,7
TOTAL	7 700	147,8		6 067	1 459,2	1 311,3	100,0
Ponds receiving pig manure and pellets			%				
Aischgrund carp	1 600	18,3	9,2	1 567	1 036,8	1 017,6	26,5
Dor 70 carp	1 600	42,8	21,5	1 363	1 134,6	1 091,9	28,4
Aischgrund x Dor 70 carp	1 600	52,8	26,5	1 375	1 299,1	1 246,3	32,4
Black carp	600	13,6	6,8	500	134,4	120,8	3,1
Grass carp	600	4,1	2,1	263	68,3	64,2	1,7
Silver carp	1 700	3,1	1,6	1 163	213,9	210,8	5,5
O. mossambicus	1 700	64,4	32,3	1 508	159,5	94,9	2,5
TOTAL	9 400	199,1		7 739	4 046,6	3 846,5	100,0

the pond water induced by the addition of the manure. The addition of pelleted fish feed did not produce materially higher yields in silver carp, which was in fact the case with black carp and to some extent with grass carp.

Even though relatively large numbers of the cichlid *O. mossambicus* were included in the pig manure and pellet pond systems, this fish species does not appear to contribute much towards the total yield of fish in this specific experiment.

Concluding Remarks

The integration of pig and fish farming is a common practice in countries such as Hong Kong and Taiwan where pig faeces are directly washed into the fishponds from the piggery or passed through a simple digester system, where solids are trapped and the nutrient-rich liquid is diverted to the ponds for algal growth. Little has, however, been published on the fish used (which are mainly Chinese carps) nor on the actual fish-production potential of this kind of system.

Some work on the integration of pig and fish farming has been done in Africa where the tilapia *O. niloticus* and *Clarias lazera* (C & V) are produced together in ponds receiving pig manure, with apparently good results, yielding as much as 4 800-7 700 kg $ha^{-1}yr^{-1}$ (Vincke, 1976 and Miller, 1976; 1977). *Clarias lazera* is apparently used as predator – in this case to harvest wild spawns of tilapia in the ponds.

In Northern America, Buck *et al.*, (1979) recycled swine manure through fish ponds and by using a fish polyculture system in which the Chinese silver, bighead and grass carps are combined with the Israeli common carp and the hybrid buffalo, channel catfish and large mouth bass, they were able to produce between approximately 3-4 t $ha^{-1}yr^{-1}$. Environmental conditions for experiments done by Buck *et al.*, (1979) appear to have been more favourable than in the present experiment at the Umtata Dam Fish Research Centre, as water temperatures recorded there fell below 20 °C only briefly, with mean surface temperatures in the ponds usually exceeding 24 °C.

In South Africa, Krause (1980) reported on the integration of pig farming with the monoculture of Aischgrund carp. A total of 16 000 juveniles were stocked in a 3 726 m^2 pond. Krause was able to grow the juveniles to sizes of 250-300 g within three months.

During the 160 day period of the Umtata polyculture experiment, more than 42 t of fresh pig manure, equivalent to 10,5 t dry mass per ha were introduced into the set of three ponds receiving pig manure alone, with no apparent deleterious effects on the water quality or on fish growth. In fact, judging by the experience of research workers such as Buck *et al.*, (1979), only the rapidly decreasing water temperatures, interfered with the fish production capacity of the Umtata fish-ponds.

In the case where pelleted fish feed was combined with manure, the contribution of the latter towards the overall reduction in the amounts of fish feed needed to produce 1 kg of fish was very apparent, and with a production of more than 40 kg $ha^{-1}d^{-1}$, the total potential fish yield can be much higher than the 4 t/ha obtained.

The present experiment also shows that in Transkei or in similar climatic regions elsewhere in southern Africa, any venture of this nature should be put into operation during the early summer (November) when mean water temperatures already exceed 20 °C. Then the direct and indirect utilization of the pig manure by most of the fish species used in the present study will be good. It is also recommended that initial stocking be done, where possible, with young fish which have been overwintered. The use of fish spawned during the same season delays the onset of production until the middle of the summer season.

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