A PRACTICAL INVESTIGATION INTO CATFISH (*CLARIAS GARIEPINUS*) FARMING IN THE VAALHARTS IRRIGATION SCHEME

By

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BACKGROUND TO VAALHARTS IRRIGATION SCHEME

The history of the Vaalharts Irrigation Scheme started back in 1881 – 1882 when the Irrigation Engineer of the Cape surveyed the area for possible irrigation purposes. He reported his findings to the Prime Minister of the Cape Colony, Cecil John Rhodes, who proposed the building of the Vaalharts Irrigation Scheme to the Cape Parliament. Although the Cape Parliament accepted the proposal, there was no funding to complete such a large project (De Jager, 1994). After various postponements it was only in November 1933 that the government announced that it would build the Vaalharts Irrigation Scheme. The first plots were allocated during 1957 and 1958 and the last in 1965 and 1966. Because of the flat gradient of the area, natural and sub-surface drainage was very poor and over the years flood irrigation has raised the ground water table from 24 m to 1 m. To overcome this problem sub-surface drainage systems were constructed in the 1970's. To decrease seepage of irrigation water, the irrigation dams, one main furrow and some lateral furrows were lined with concrete (Herold and Bailey, 1996). The irrigation plots averaged 25 ha in size and the irrigation dams on average 2 500 m^2 (Figure 1).

By 1983, 832 irrigation dams had been lined with permanent cement lining in order to reduce losses through seepage (Herold and Bailey, 1996). This figure should have increased considerably in the interim and almost every irrigation dam out of the original 1 175 dams had been permanently lined with cement.

The Vaalharts region is subjected to large daily and seasonal temperature changes. The average maximum temperature for the last 50 years until 1984 was 26.6ºC and the average minimum temperature was 10.5ºC. A distinct hot and cold season can be distinguished with the highest temperature recorded 41.2ºC and the lowest -9.3ºC. Frost is a common occurrence in winter. The

region is classified as a summer rainfall region. The rainy season lasts from October to March with a peak in rainfall during January and February (Stëyn, Ellis and Van der Linde, 1991).

Figure 1. A typical irrigation dam in the Vaalharts Irrigation Scheme.

Farmers are currently leaving agriculture at an alarming rate in South Africa. Between 1950 and 1987 almost half of South Africa's farmers left agriculture. Because of various economic factors negatively impacting on farmers, only 65 170 of the estimated 446 848 farmers were still farming in 1987 (Stëyn *et al.*, 1991). This led to the amalgamation of various farming units and a reduction in the spatial distribution of services provided, because of the decrease in people living in the rural areas.

The urbanization of farmers is a big problem in the Vaalharts Irrigation Scheme where the original purpose of the development of this scheme was the creation of job opportunities through the development of a large number of 25 ha plots (Figure 2). Although these 25 ha plots were originally large enough to provide a good annual income and quality lifestyle, this is, however, no longer the case. The only solution to this problem is the development of alternative farming practices. This could be done through the use of

alternative crops or by improving the utilization of existing natural resources on each farm.

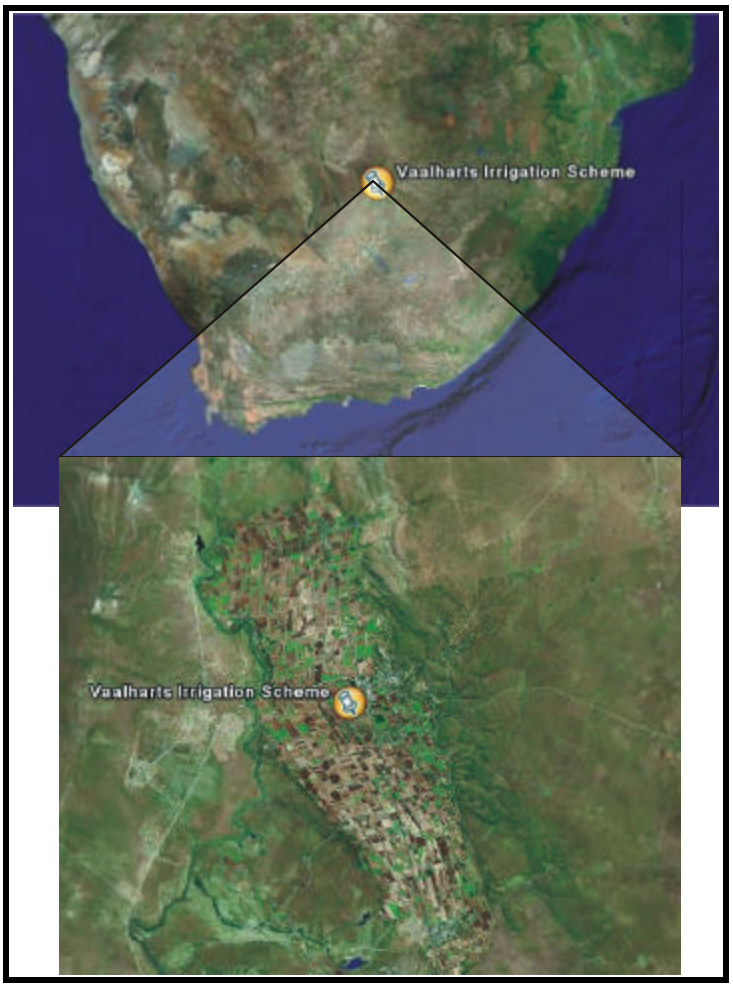

Figure 2. A satellite photo of the Vaalharts Irrigation Scheme (www.googleearth.com).

The farmers of the Vaalharts Irrigation Scheme together with the government, have, unwittingly, created an aquaculture infrastructure worth millions for aquaculture. The irrigation scheme presents immense opportunities for aquaculture in the region. By combining aquaculture via the use of the irrigation dams into the farmers' normal agricultural practices, an integrated farming unit is created that should result in:

- Better utilization of natural resources,

- Job creation,
- Improved annual income, and
- Improvement in food security.

1.1 BACKGROUND TO AQUACULTURE

Aquaculture has been the world's fastest growing food production system over the past decade. The average growth rate for aquaculture has been 8.9% per year since 1970, compared to only 1.2% for capture fisheries and 2.8% for terrestrially farmed meat-production over the same period (Brink, 2001). In 2002 the total contribution of aquaculture towards total world fish requirements was 29.9% (FAO, 2004). North American and European markets have shown a continuous growth of 10 to 15% per year, particularly in respect to shrimp, salmon, trout, catfish and tilapia. This implies that a production of 16 000 tons of aquaculture products per year is needed to meet the increase in demand (Brink, 2001). Production from aquaculture has greatly outpaced population growth, with the world average per capita supply from aquaculture increasing from 0.7 kg in 1970 to 6.4 kg in 2002 (FAO, 2004).

The reason for the exceptional growth rate in aquaculture is mainly due to marine stock depletion. There has been a consistent downward trend since 1974 in the proportion of stocks offering potential for expansion, coupled with an increase in the proportion of over-exploited and depleted stocks, from about 10% in the mid-1970s to close to 25% in the early 2000s (FAO, 2004). The conservation of our natural fish resources is therefore of great importance and consequently major fish consuming countries such as China have adopted a zero growth policy with regard to their oceanic catches (FAO, 2004). Not only can countries protect their natural fish resources through the development of sustainable aquaculture, but also better the utilization of one of the most important natural resources in the world, fresh water. This can be achieved through the incorporation of aquaculture into agriculture by irrigating crops with nutrient enriched water supplied by ponds used for fish farming.

The culture of food fish is mainly practiced (57.7%) in freshwater. The developing countries accounted for 90.7% of production in 2002, consisting mainly of herbivorous/omnivorous or filter-feeding species (FAO, 2004). According to the FAO's review of the state of world aquaculture 2004, Africa contributed only 0.4% to total world aquaculture production and it is estimated that less than 5% of the aquaculture potential of Sub-Saharan Africa is currently used. With regard to finfish production in Sub–Saharan Africa, tilapia was the most important group produced in 1995 and catfishes the second most important. The most important catfish produced was *Clarias gariepinus* with a total production of 4 000 mt and production value of $11.8 million (Pedini, 1997). Aquaculture has shown a significant increase in South Africa over the past decade. Total production has increased from 3 000 tons in 1997 to 5 800 tons in 1999 with a value of R144 million. During the year 2000 South Africa produced 65 metric tons of catfish (*C. gariepinus*) with a production value of R667 000 (Brink, 2001).

Sub-Saharan Africa, however, is facing problems with regard to the adoption and sustainability of aquaculture and development momentum is yet to materialize. As noted by Pedini (1997), these problems encompass, a) poor macro environment for development, b) limited financial resources, c) the novelty of aquaculture as a food-producing system and it's low priority in development plans, d) frequent droughts and water shortage, e) lack of cohesive aquaculture development plans and firm commitment to its promotion, f) rural aquaculture development inconsistent with the needs and circumstances of rural communities and family economies and g) promotion of aquaculture as a stand- alone activity.

These problems were diagnosed in the early eighties and were still valid in the early 1990s, suggesting that many governments and donors had not yet responded to the need for a change in development approach. However, a paradigm shift in both research and development strategies is in progress in Sub-Saharan Africa based on research and development of the concept of aquaculture as a component of integrated farming activities based largely on

the use of on-farm resources. Although integrated aquaculture-agriculture has been demonstrated to provide benefits from existing resources under certain conditions and with proper planning, research efforts to identify opportunities for integration and to document their economic impact are scarce (Pedini, 1997).

According to Brink (2001), aquaculture in South Africa is mainly focused on the production of high priced species (abalone, oyster, mussels, trout and ornamental species, etc), directed towards niche markets within southern Africa as well as the import markets of developed countries. Little emphasis is, however, placed on the production of affordable animal protein for the purpose of food security. This is mainly due to the fact that aquaculture development in South Africa at present is market orientated and driven by both corporate and entrepreneurial participation with emphasis on economic earnings. The lack of involvement by government is one of the main reasons why little attention is given to the development of aquaculture activities contributing towards job creation, human resource development and food security.

Farming with some of these high value species such as trout, ornamental fish and freshwater crayfish may have serious ecological consequences associated with them. The import of non-endemic species for aquaculture and recreational purposes in the past has resulted in major ecological tragedies. For example the introduction of carp (*Cyprinus carpio*) has resulted in the destruction of numerous freshwater habitats due to the feeding behavior of this omnivorous fish. The introduction of predatory fish like trout and bass species also threatens the survival of many of our endemic smaller fish species on which these predators prey. Aquaculturists should therefore be sensitive to the dangers associated with the translocation of alien species.

1.2 DISCUSSION

Against this background the idea of catfish (*Clarias gariepinus*) farming in the Vaalharts irrigation dams was born. *Clarias gariepinus* is the only endemic species in the Vaalharts Irrigation Scheme, which has proven itself in various studies as a viable aquaculture species. These catfish are efficient opportunists and survivors, equipped to exploit whatever resources are available. They have a wide tolerance to environmental extremes and based on field studies conducted by Bruton (1988), their tolerances are as follows:

- Water temperature: 8 to 35ºC; breeding > 18ºC.
- Water temperature range for egg hatching 17 to 32ºC.
- Salinity, 0 to 12 ppt, 0 to 2,5 ppt is optimal.
- Oxygen, 0 to 100% saturation. It is an efficient and obligate air breather, which will drown if denied access to air.
- Desiccation, a strong resistance to desiccation as a result of their air breathing habits.
- PH, wide tolerance.
- Turbidity, wide tolerance.
- Sibling densities, wide tolerance.

Clarias gariepinus is regarded as an excellent aquaculture species, not only for their tolerance to environmental extremes, but also:

- **Their High Annual Production**

  Production of *Clarias batrachus* in Thailand and *C. gariepinus* in Zambia indicate that a standing crop of 65 to 100 tons/ha is attainable (Uys and Hecht, 1988).

- **Their Good Feed Conversion Rate**

  Feed conversion rates of up to 1.05 were found in experimental least cost diets containing 38% crude protein (Uys, 1988).

- **Successes with Catfish Farming all over the World**

  Catfish farming is at present a very big industry in countries all over the world. The global production of catfish as food fish was estimated to be about 320 000 metric tons in 1992 (Losordo, Masser and Rakocy, 1998).

The production of *C. gariepinus* in the Vaalharts Irrigation Scheme was originally the brainchild of the Des Puttick and Roy Kannemeyer, owners of the Vaalharts *C. gariepinus* hatchery. After a visit to the Vaalharts hatchery, the project of determining the feasibility of *C. gariepinus* farming in the Vaalharts Irrigation Scheme was born.

Although a lot can be learnt about *C. gariepinus* farming through controlled laboratory studies, the feasibility of catfish farming in the Vaalharts Irrigation Scheme can only be established through the actual production of fish in the irrigation dams. Considering the size of the irrigation dams, even at low fish stocking densities, large amounts of expensive feed would be required. This led to the involvement of a private company together with Des Puttick and Roy Kannemeyer, to finance the production of *C. gariepinus* in a single irrigation dam. The data obtained from the stocking and grow out of *C. gariepinus* in this dam could then be used to determine the feasibility of catfish farming in the area and consequently the expansion of the fish farming operation. Since the production of *C. gariepinus* in the irrigation dam was a private business, the extent of experiments that could be done was limited. Nevertheless, this business venture presented a valuable opportunity for research on the large scale production of *C. gariepinus* in South Africa.

The objective of the present study was to produce a dissertation that could be used as a practical handbook by farmers in the Vaalharts Irrigation Scheme for *C. gariepinus* farming in this area. This was achieved by researching and discussing the five most important themes in fish farming, namely: production

(Chapter 2), nutrition (Chapter 3), disease (Chapter 4), disease treatment (Chapter 5) and processing and marketing (Chapter 6).

PRODUCTION

2.1 INTRODUCTION

Catfish are currently produced worldwide using various production systems ranging from very low yielding extensive systems to high yielding intensive systems. The choice of a system suitable for the species intended for production is probably the most important decision for any prospective aquaculture farmer, and may either result in the success or failure of any aquaculture business. Production systems can be categorized as stagnant pond, flow-through pond, recirculation pond production or raceway production. These production systems differ to a greater or smaller degree from each other in regard to the intensity of production, production costs and technical difficulty in operating and managing them. In choosing a production system, the following factors must be taken into consideration:

The Cultured Species

The optimal conditions required for maximum production of a particular species, for example water temperature, water oxygen levels and water quality will be determining factors in what production system should and should not be used.

Location of Production System

The climate and environment of the area chosen in which to produce a species will determine what production system should be used. For example, if optimal conditions occur naturally, production systems exposed to ambient environmental conditions such as earthen ponds, raceways and cages must be used. Otherwise production systems with full environmental control like closed recirculation systems are the only other option.

Aquaculture Regulations

There are numerous regulations, which apply within the general area of aquaculture that potential producers should be aware of. These regulations must be considered in decision-making regarding:

- Site selection,
- Construction,
- Water supply,
- Culture species, and
- Product processing and marketing.

All provincial Nature Conservation Departments have ordinances, with specific regulations for fish farming that must be consulted before planning any production system.

Financial Considerations

The aim of any business endeavor is the realization of maximum profit margins. The production of an aquaculture species as a business is no different. Over-capitalization could result in the failure of an aquaculture business, therefore the cost and production capabilities of any production system must be evaluated carefully.

All the various methods of spawning and raising catfish are effective under specific conditions and the factors influencing the success of these methods must carefully be evaluated in the area intended for fish culture. In the Vaalharts Irrigation Scheme two production systems are currently used to produce *Clarias gariepinus*. The first method is a flow-through system using tarpaulin ponds fed by continues pumping of underground water. This system is primarily used for hatchery ponds but also alternatively serves as grow out

ponds. The second method is an integrated semi-stagnant pond production system using an irrigation dam as a fish grow out pond. This production system is integrated into the normal irrigation practices of the farmer providing him with nutrient enriched irrigation water.

The effectiveness of any production system must be evaluated through the growth performance of the fish produced in the specific system. The growth performance of fish is expressed as weight gained per day (growth rate) or percentage of weight gained per day (specific growth rate). Both the above mentioned growth parameters provides valuable information regarding the growth performance of fish. The overall performance of a production system must only be evaluated if water temperatures, that have a considerable influence on the growth rate of *Clarias gariepinus*, are also considered in the equation. Consequently the water temperatures and growth rate of fish stocked in the Vaalharts irrigation dam and flow-through pond were recorded and compared. The objectives of the study were:

- To record the spawning procedures used by Roy Kannemeyer.
- To determine the growth rate and specific growth rate of fish stocked in the irrigation dam.
- To determine the growth rate and specific growth rate of fish in the flow-through pond.
- To determine the daily water temperatures in the irrigation dam and flow-through pond for one year.
- To develop a practical method that is usable for fish farmers to estimate fish survival in the irrigation dam based on feed consumption.

2.2 MATERIAL AND METHODS

Spawning Procedures

The spawning procedures, used by Roy Kannemeyer, were observed, recorded and summarized to serve as a practical guideline for the spawning procedures currently used in the Vaalharts hatchery.

Growth Rate and Specific Growth Rate of Fish Stocked in the Irrigation Dam

A total of 16 776 *Clarias gariepinus* fingerlings with an average weight of 8.9 g were placed in the irrigation dam which served as the grow out pond on 12/11/2004 (Figure 1). A screen was installed in the inlet of the irrigation dam to prevent the fish from escaping (Figure 2). The fish initially fed on natural feed present in the dam and the feeding pellets were only added a week later on 19/11/2004. The feed fed to the fish was recorded over a period of 216 days from 19/11/2004 to 29/06/2005. Fish were initially fed crushed 4 mm pellets by hand three times a day until they were able to consume whole 4 mm pellets after which a pendulum self-feeder was introduced at the beginning of January 2005 (Figures 3 and 4). The average weight of fish at this time was 55.8 g. Approximately at the same time predation by piscivorous birds was observed for the first time and a worker was employed to prevent predation by daily chasing the birds away. On ten separate occasions samples of the fish in the pond were netted (Figure 5). The sample size and weight of the sample were recorded and the average weight of the fish was consequently calculated using this data. The average weight of the fish in the irrigation dam was also used to calculate the average weight gain, growth rate (g/day) and specific growth rate (% of body weight/day) between each sample time point.

The growth rate and specific growth rate were calculated using the following formula suggested by Uys and Hecht (1988):

$$\text{Growth rate} = \frac{W1 - W0}{T}$$

Where W0 = Average weight of fish recorded at first time point.
W1 = Average weight of fish recorded at second time point.
T = Days between two time points.

$$\text{Specific growth rate} = \frac{\text{Log (W1)} - \text{Log (W0)}}{T} \times 100$$

Where W0 = Average weight of fish recorded at first time point.
W1 = Average weight of fish recorded at second time point.
T = Days between two time points.

Figure 1. **Photographs of the fingerling *Clarias gariepinus* stocked in the irrigation dam in the Vaalharts Irrigation Scheme.**

Figure 2. **A photo of the screen preventing fish from escaping through the inlet of the irrigation dam in the Vaalharts Irrigation Scheme.**

Figure 3. **A photograph of the irrigation dam used for the grow out of *Clarias gariepinus* in the Vaalharts Irrigation Scheme.**

Figure 4. A photograph of the pendulum self feeder used to feed fish in the Vaalharts irrigation dam.

Figure 5. **A photograph of a fish sample of *Clarias gariepinus* netted from the irrigation dam in the Vaalharts Irrigation Scheme.**

Growth Rate and Specific Growth Rate of Fish Stocked in the Flow-Through Pond

A total of 2 316 *C. gariepinus* fingerlings with an average weight of 17.52 g were stocked at an initial stocking density of 40.58 kg/m³ in a 1 m³ tarpaulin flow-through pond (Figure 6). The flow rate of the water in the pond was approximately 1 m³/hour. The same feed as that used in the irrigation dam was used in the tarpaulin flow-through pond to compare the growth rates of fish produced in a flow-through system to that of fish produced in the semi-stagnant irrigation dam. Fish samples were taken at an approximately weekly to monthly basis and the average weight of the fish and growth rates were calculated using the same formulae as mentioned above.

Daily Water Temperatures in the Irrigation Dam and Flow-Through Pond

Temperatures were recorded every four hours over a period of one year using electronic thermocouples submerged on the bottom of the irrigation dam and a flow-through pond. The data recorded was used to calculate the average monthly temperatures as well as the monthly range of temperatures.

Figure 6. A photograph of the tarpaulin flow-through ponds used in the Vaalharts hatchery.

Estimated Fish Survival Based on Feed Consumption

Good management practices and future planning by farmers require the need for accurate estimations of the current fish stock present in a dam. Since it is impractical to harvest and count all the fish in a dam, estimations must be based on sub-samples of fish netted and on feed consumption. Because of the need for relatively accurate estimations of the fish stock present in the irrigation dam, a formula was developed to predict the percentage survival of the fish. The estimated percentage survival of fish was based on feed consumption and measured average weight and was calculated using the following formula:

$$\text{Estimated percentage survival} = \left(\frac{\text{WFS} + \text{PG}}{\text{MW}} \div \text{NFS} \right) \times 100$$

Where WFS = Weight of fish stocked.

PG = Pond gain based on weight of feed fed and an established feed conversion rate (FCR), for example if 15 kg of feed was fed over a period and the FCR for the specific feed has been established at 1.5 the pond gain would be 10 kg.

MW = Measured average weight of fish in netted sample.

NFS = Number of fish originally stocked in pond.

2.3 RESULTS

Spawning Procedures

Artificial spawning was induced by hypophyzation, which involved the injection of a female fish with pituitary gland homogenate obtained from carp (*Cyprinus carpio*) to stimulate final egg maturation and ovulation. The injections were prepared by homogenizing pituitary glands in a small quantity of distilled water. This pituitary homogenate was subsequently drawn into a hypodermic syringe and injected intramuscularly into a female fish in the nape region.

Female fish were injected in the afternoon between 18:00 and 19:00 followed by hand stripping the following morning. After injection with the pituitary homogenate, female fish were placed in separate tarpaulin flow-through ponds. At approximately 08:00 the following morning the female fish were examined to established whether they were ready for spawning. This was done by checking if eggs were spontaneously extruded from the genital papilla. The fish that were ready for spawning were removed from the tanks for stripping of eggs.

The stripping procedure involved two people, one person holding the head of the fish with the one hand while stripping the fish with the other, while the second person held the tail of the fish and the receptacle in which to collect the eggs with the other hand. Prior to stripping, the abdomen of the female

was dried with absorbent paper to prevent water coming into contact with the eggs prematurely. Stripping was affected by applying even pressure down the abdomen of the fish towards the genital papilla using the thumb alternatively on the right and on the left side of the female fish. The fish was stripped until traces of blood were observed which signified that the ovaries were empty.

A male fish was subsequently anaesthetized and its testes were removed. The testes were slit along the distal margin using a blade and the semen squeezed over the eggs. The semen was added to the eggs within 30 seconds after removal of the testes and was gently mixed with the eggs using a soft rubber spatula. A small quantity of water was added which caused the eggs to swell and become adhesive. Stirring and adding of water continued for approximately five minutes. The fertilized eggs were subsequently added to a tarpaulin flow-through hatchery pond with a suitable substrate such as pine tree branches for the eggs to adhere to. The water flow rate in the ponds was approximately one complete water exchange per hour. The eggs hatched within 24 hours and the larvae started to feed two days after hatching. Two days after hatching the larvae were fed hourly with very fine meal (Aqua Nutro Pre Starter 00) by hand for 18 hours a day. Larvae started topping which involves the supplementation of oxygen by taking gulps of air after 18 days and were graded for the first time at a length of 1 cm. Two weeks after hatching weekly prophylactic 30 minute bath treatment was started with formalin and malachite green at a dose rate of 116 ppm formalin and 3 ppm malachite green.

Growth Rate and Specific Growth Rate of Fish Stocked in the Irrigation Dam and Flow-Through Pond

The growth rate (g/day) of fish in the irrigation dam increased exponentially up to the start of the winter in May. The highest specific growth rate was recorded between 23/12/2004 and 27/01/2004 when the highest water temperatures were recorded (Tables 1 and 2). The concurrence of the highest specific growth rate and highest water temperatures emphasizes the importance of water temperatures on the growth rate of *C. gariepinus*. The specific growth rate gradually declined, as the water temperatures cooled down, followed by a sharp decline between 28/04/2005 and 29/06/2005 when average water temperatures were below 20°C (Table 2).

The growth rate and specific growth rate of fish in the tarpaulin flow-through system was, except for approximately the first twenty days, on average lower than that of fish in the irrigation dam (Table 3 and Figures 7 and 8). The movement of fish to a larger flow-through pond resulted in an initial increase in the specific growth rate after which a decline was recorded as fish increased in size and the water temperatures declined. This decline in specific growth rate as a result of declining water temperatures was also observed in the irrigation dam (Table 2).

Table 1. **The weight of feed consumed, average weight of *Clarias gariepinus*, weight gain of fish and growth rates calculated on nine separate occasions between 7 and 35 days apart in the irrigation dam.**

Date	Feed (g)	Average Weight (g)	Gain (g)	Growth rate (g/day)	Specific growth rate (% of body weight/day)
12/11/2004	No feed	8.9	N/A	N/A	N/A
19/11/2004	No feed	11.1	2.2	0.31	0.34
25/11/2004	22.10	14.17	3.07	0.51	0.38
23/12/2004	293.73	26.30	12.13	0.43	0.96
27/01/2004	799.50	95.95	69.65	1.99	1.61
03/03/2005	1975.00	229.60	133.65	3.93	1.08
31/03/2005	1835.00	391.90	162.30	5.80	0.83
28/04/2005	1400.00	554.00	162.10	5.79	0.54
02/06/2005	200.00	480.00	-74.00	-2.11	-0.18
29/06/2005	30.00	450.00	-30.00	-1.11	-0.10

Table 2. **The average weight, temperature range and specific growth rates of *Clarias gariepinus* in the irrigation dam and experimentally determined specific growth rates at different water temperatures and weights according to Hoogendoorn, Hansen, Koops, Machiels, van Ewijk and van Hees (1983), at the calculated average water temperature over the same period of time.**

Date	Average Weight (g)	Average Temperature (°C)	Temperature range		Measured specific growth rate (% of body weight/day)	*Specific growth rate (% of body weight/day)
19/11/2004	N/A	N/A	Min	Max	N/A	N/A
25/11/2004	14.17	23	22.5	25.5	0.38	4.7
23/12/2004	26.30	25	22.5	29.0	0.96	5
27/01/2004	95.95	26	23.5	29.5	1.61	2.8
03/03/2005	229.60	25	22.5	28.5	1.08	1.2
31/03/2005	391.90	23	20.0	25.5	0.83	0.9
28/04/2005	554.00	20	16.5	23.5	0.54	0.4
02/06/2005	480.00	16	12.0	22.5	-0.18	NA
29/06/2005	450.00	12	9.5	14.5	-0.10	NA

* (Hoogendoorn *et al*., 1983)

Table 3. **The weight of feed consumed, average weight of *Clarias gariepinus*, weight gain of fish and growth rates calculated on a weekly to two weekly basis for fish in 1 m³ tarpaulin flow-through ponds.**

Date	Feed (kg)	Average Weight (g)	Gain (g)	Growth rate (g/day)	Specific growth rate (% of body weight/day)
19/11/2004	N/A	17.52	N/A	N/A	N/A
25/11/2004	7.07	19.36	1.84	0.31	0.72
01/12/2004	6.67	23.08	3.72	0.62	1.27
09/12/2004	12.03	28.52	5.44	0.68	1.15
17/12/2004	11.28	32.2	3.68	0.53	0.66
*17/12/2004	37.05	32.21	14.68	0.52	0.94
23/12/2004	8.52	33.3	1.09	0.18	0.24
30/12/2004	10.7	34.2	0.90	0.13	0.17
06/01/2005	10.93	36.5	2.30	0.33	0.40
**17/02/2005	N/A	67.12	N/A	N/A	N/A
03/03/2005	83.82	92	24.88	1.78	0.98
17/03/2005	59.36	102.5	10.50	0.75	0.34
31/03/2005	56.5	104	1.50	0.11	0.05
14/04/2005	43.8	105.2	1.20	0.09	0.04

* All the fish in pond counted and weighed, growth rate and specific growth rate calculated from start date.

**Fish from two ponds added together and moved to a bigger pond, calculations started over.

The specific growth rate of fish in the tarpaulin flow-through pond also decreased with an increase in fish density >53.45 kg/m³ (Table 4). The decreasing specific growth rate took place irrespective of a relatively high water flow rate of 1 m³/hour.

Table 4. **The specific growth rate of *Clarias gariepinus* in the tarpaulin flow-through pond at the various calculated stocking densities and experimentally determined specific growth rates of *Clarias gariepinus* at different water temperatures and weights according to Hoogendoorn, Hansen, Koops, Machiels, van Ewijk and van Hees (1983).**

Date	Average Weight (g)	Total weigh (kg)	Average Temperature (°C)	Density (kg/ m³)	Specific growth rate (% of body weight/day)	*Specific growth rate (% of body weight/day)
19/11/2004	17.52	40.58	N/A	40.58	N/A	N/A
25/11/2004	19.36	44.84	24	44.84	0.72	4.4
01/12/2004	23.08	53.45	23	53.45	1.27	3.8
09/12/2004	28.52	66.05	24	66.05	1.15	4.4
17/12/2004	32.2	74.58	24	74.58	0.66	4.4
23/12/2004	33.3	77.12	24	77.12	0.24	4.4
30/12/2004	34.2	79.21	24	79.21	0.17	4.4
06/01/2005	36.5	84.53	26	84.53	0.4	5.4

* (Hoogendoorn *et al*., 1983)

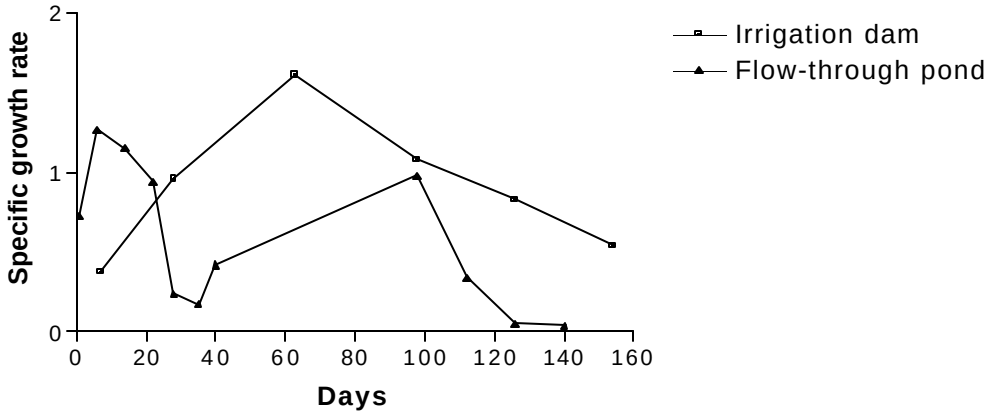

Figure 7. **A comparison between the specific growth rates of *Clarias gariepinus* in the flow-through pond and the irrigation dam between the days that samples were taken starting from 25 October 2004 to 28 April 2005.**

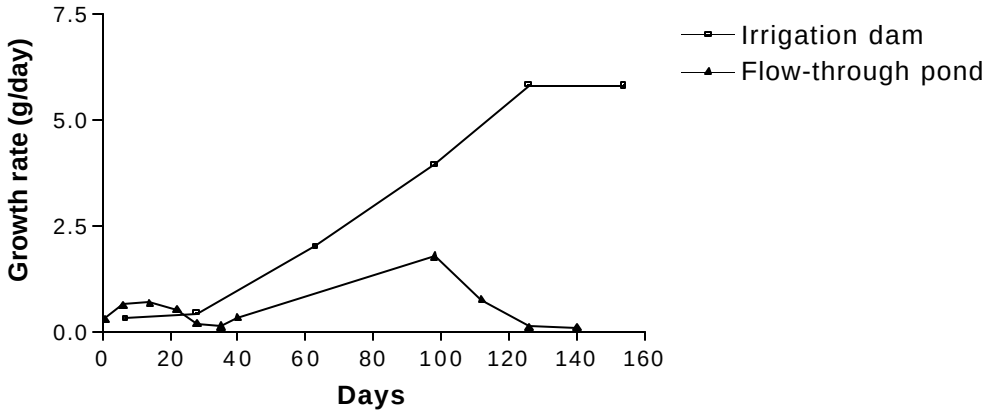

Figure 8. **A comparison between the growth rates of *Clarias gariepinus* in the flow-through pond and the irrigation dam between the days that samples were taken starting from 25 October 2004 to 28 April 2005.**

Water Temperatures

The average monthly water temperatures in the irrigation dam ranged between 11.3°C (July) and 26.1°C (January) resulting in a 14.8°C difference between the highest and the lowest monthly average temperature (Table 5 and Figure 9). The range in monthly average water temperatures was markedly higher than that of the tarpaulin flow-through pond where the temperatures ranged between 26.0°C (February) and 16.0°C (September) resulting in a 10°C difference (Table 5 and Figure 10).

Table 5. **The average monthly temperatures and range of temperatures recorded in the irrigation dam and the tarpaulin flowthrough pond over a period of one year.**

	Irrigation dam			Hatchery flowthrough pond		
	Average	Maximum	Minimum	Average	Maximum	Minimum
January	26.1	29.5	22.5	25.0	29	20
February	25.3	28.5	22.5	26.0	29	23.5
March	22.8	26	20	23.4	27	21
April	20.2	23.5	16.5	20.8	24	17
May	16.0	20.5	12	18.0	23	9.5
June	11.8	15	9.5	16.6	21.5	13
July	11.3	13.5	9	17.4	21.5	13.5
August	13.7	16.5	9	17.7	22	12.5
September	16.0	21	12	16.0	21	12
October	20.2	24.5	15	20.2	24.5	15
November	24.0	27.5	19	23.2	27.5	19
December	25.2	28.5	23.5	24.3	28	21.5

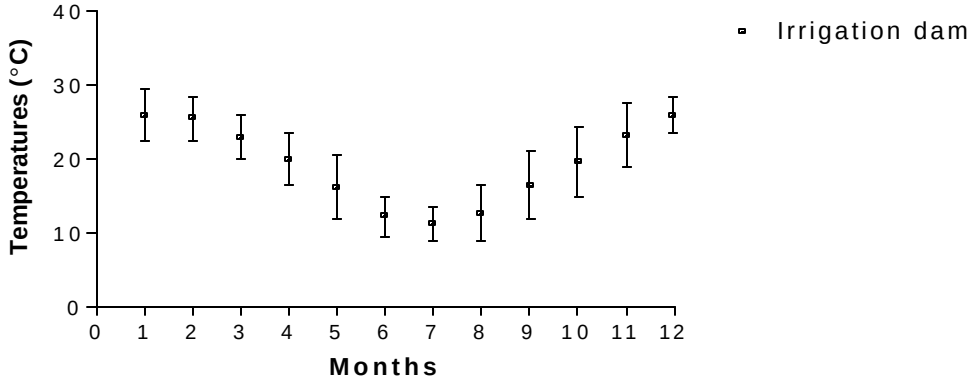

Figure 9. **The monthly average and range of temperatures recorded in the irrigation dam over a period of one year.**

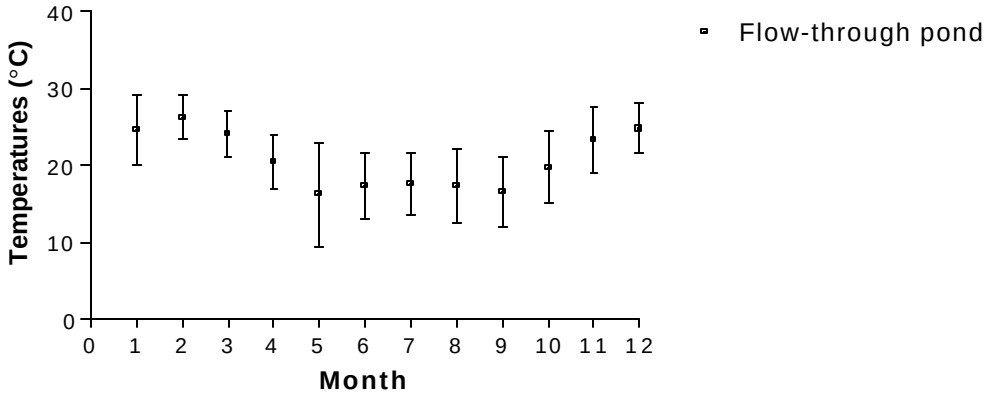

Figure 10. **The monthly average and range of temperatures recorded in the tarpaulin flow-through pond over a period of one year.**

Estimated Fish Survival Based on Feed Consumption

The calculated estimated percentage survival of fish in the irrigation dam declined from 89.10% on 23/12/2004 to 73.81% on 29/06/2005. These two calculations were regarded as the most accurate because of the larger sample sizes (Table 6). The estimated decline in percentage survival coincides with observations of predation by birds on fish bigger than 50 g.

Table 6. **The calculated percentage survival of *Clarias gariepinus* stocked in the irrigation dam based on the estimated total weight of the fish in the pond (Total fish weight = weight of feed fed ÷ 1.2 feed conversion rate), measured average weight of fish and total fish stocked in the pond (n=16776)**

Date	n (sample size)	Total weight of fish in pond	Average Weight	% Survival
25/11/2004	94	167.65	14.17	70.53
23/12/2004	151	393.11	26.30	89.10
27/01/2004	41	1 056.69	95.95	65.65
03/03/2005	43	2 695.94	229.60	69.99
31/03/2005	37	4 218.99	391.90	64.17
28/04/2005	37	5 380.99	554.00	57.90
02/06/2005	50	5 546.99	480.00	68.89
29/06/2005	150	5 571.89	450.00	73.81

2.4 DISCUSSION

Hatchery Production

Intensive research has been done with regard to the artificial propagation of *Clarias gariepinus*. Techniques used to induce spawning by hypophyzation are well documented and described by various authors. These methods were particularly well described by Britz (1991) as well as Schoonbee and Swanepoel (1988). The following is a summary of the methods described by the above mentioned authors.

Before spawning can be induced by hypophyzation, gravid females must first be identified. *Clarias gariepinus* displays a seasonal gonadal cycle and gravid females may be found from spring (October) until water temperatures drop in autumn (March/April). Ripe females can be identified by their distended bellies and usually red and swollen genital papillae. The ripeness of ova can be confirmed by sucking up ova into a tube and inspecting the eggs which should have a firm, translucent appearance and a diameter =1 mm. The color of ova may vary, but if the ova are yellow and opaque with a “runny” texture, re-absorption has begun and it is too late to attempt induced spawning induction. It is not possible to judge externally whether male catfish have developed testes but viable sperm should be present in males if gravid females are present in the same water body (Britz, 1991). When a gravid female is identified, spawning can be induced by injecting the female with an appropriate hormone. A variety of natural and synthetic hormones can be used, but the use of homoplastic pituitary glands; that is pituitaries taken from the species being hypophysized, is the technique most widely used (Table 7).

Clarias gariepinus pituitary glands can be collected by the method described by Schoonbee and Swanepoel (1988) using a 45 mm diameter hole-saw to cut through the dorsal surface of the skull. The hole is made through the pariental and frontal bones just in front of the posterior fontanel and is then cut

down through the pro-otic and exoccipital bones stopping just short of the parasphenoid at the base of the brain. After the saw has been removed and the circular plug of bone is lifted out drawing with it the brain and pituitary gland, the pituitary gland should be clearly visible as a distinct white, pea-shaped organ (± 1 mm diameter in a 1 kg fish) (Britz, 1991). Pituitary glands should only be collected during summer when the levels of pituitary gonadotrophic hormone are high. The collected pituitaries should be preserved whole in 95% alcohol and then stored in a refrigerator (2 – 5°C) for 2 – 3 years (Britz, 1991).

Table 7. Substance used for hormonally induced spawning of *Clarias gariepinus* (adapted from Britz, 1991).

Substance	Species
Desoxycorticosterone acetate (DOGA)	*Clarias gariepinus*
Carp pituitary suspension (cPS)	*Clarias gariepinus*
Human chorionic gonadotropin (hCG)	*Clarias gariepinus*
Carp PS + hCG	*Clarias gariepinus*
Clarias pituitary suspension	*Clarias batrachus* *Clarias macrocephalus* *Clarias gariepinus*
Progestagen (17¯alpha-progesteroe)	*Clarias gariepinus*
Pimozi de + LHRHa	*Clarias gariepinus*

Table 8. The latency time in relation to temperature between hypophyzation and spawning for *Clarias gariepinus* (adapted from Britz, 1991).

Water Temperature (°C)	Latency Time (h)
20	21
21	18
22	15.5
23	13..5
24	12
25	11
26	10
27	9
28	7.5
29	7

The pituitary dosage used is dependent on the weight of the donor and recipient fish and the time of year when the pituitary glands were collected. For a donor and recipient fish of similar weight, a single homogenized pituitary gland collected in summer will be sufficient to induce spawning (Britz, 1991).

The pituitary dosage must be prepared by removing the appropriate amount of pituitaries from the alcohol and placing them on a paper towel to allow the alcohol to evaporate. The pituitary glands are then homogenized together with a small volume (± 0.5 ml) of sterile water in a tissue grinder (Britz, 1991). The homogenate must then be further diluted with sterile water so that each fish will receive approximately 1 ml of solution injected intramuscularly next to the dorsal fin. The latency time between hypophyzation and spawning is temperature dependent and is summarized in Table 8.

After the estimated time between hypophyzation and spawning has elapsed the female fish must be examined and if ova are spontaneously extruded from the genital papilla, the female is ready for stripping.

Hatchery Procedures

Various procedures for hatching *C. gariepinus* eggs have been developed. These procedures vary mainly in the extent of mechanical handling of fertilized eggs resulting in significant differences in embryo survival. Laboratory studies have demonstrated that the survival of embryos is decreased through procedures involving a high degree of mechanical handling of eggs like during egg separation procedures in the funnel breeding technique. When the methods mentioned above are compared to direct hatching procedures in trays, a significant difference in embryo survival was recorded (Polling, van der Waal, Schoonbee and van der Waal, 1987). Substrates to which eggs can adhere varying from mesh trays to pine tree branches seem to be effective in hatcheries. The more important factors influencing larval survival are, however, hatchery design, water temperature, water flow rate and prophylactic parasitic treatment.

Hatchery Design

Wide shallow tanks with a diameter to depth ratio of about 10 are most suitable for raising *C. gariepinus* larvae. These tanks are preferred to narrow deep tanks with higher current speeds, which result in higher activity costs for fry (Haylor, 1992). Light and cover is also a very important factor influencing the growth of larvae and must be considered when designing a hatchery. The growth rate of larvae increases with shorter light periods, the highest being recorded in continuous darkness. If *C. gariepinus* are not raised under continuous darkness cover also enhances the growth rate of larvae (Britz and Pienaar, 1992). The lighting regimen also affects territorial aggression, which becomes negligible in fish raised in continuous darkness (Britz and Pienaar, 1992).

Water Temperature

Juvenile *C. gariepinus* fish are very sensitive to fluctuations in water temperature. The sensitivity of juvenile fish to water temperature fluctuations are age dependent, the younger the fish are, the more sensitive they are. The survival of five day old fish is negatively affected by a decrease in temperature from 25°C to 15°C. In contrast to this, 21 day old fish are not negatively affected by the same temperature change (Hoffman, Prinsloo, Pretorius and Theron, 1991). It is therefore important to isolate a hatchery against environmental temperature fluctuations caused by changing climatologic conditions. The majority of hatcheries are therefore indoors, where semi or full environmental control can be achieved. In the Vaalharts Irrigation Scheme, however, *C. gariepinus* larvae have been raised very successfully outdoors in the summer by Roy Kannemeyer and Des Puttick irrespective of the slight risk of a sudden drop in water temperatures.

Water Flow Rate

The optimal water flow rate for larvae will be one which provides sufficient oxygen without generating a current velocity fast enough to cause them to

swim against it. Once fry are air breathing the optimal current is simply that which does not elicit swimming (Haylor, 1992). According to Hecht (1982), the recommended water flow rate for larvae stocked at a density of 250-300 fish/liter is 200 l/hour.

Prophylactic Parasite Treatment

Parasitic infestations in *C. gariepinus* larvae can lead to major losses in any hatchery (see Chapter 4: Catfish disease), consequently the practice of prophylactic parasitic treatments is mandatory in any hatchery. According to Theron, Prinsloo and Schoonbee (1991), mortalities of *Clarias gariepinus* juveniles treated with one hour formalin baths at a dose rate of 200 ppm varied between the ages of four day, 12 day and 20 day old fish. Mortalities recorded were 1.7% in four day old fish, 1.0% in 12 day old fish and 16.3% in 20 day old fish 72 hours after treatment. This higher mortality in older fish may to some extent have been due to the development of the subbranchial membrane and the epibrandchial organ in these fish (Theron *et al.*, 1991). Juvenile *C. gariepinus* fish are most sensitive to formalin treatments at an age of 20 days. If the formalin treatments discussed in Chapter 5 are considered, where no fish died after a one hour 250 ppm and 500 ppm formalin treatment, 200 ppm treatments should be safe for fully developed fingerlings. Currently prophylactic 30 minute 116 ppm formalin bath treatments are used in the Vaalharts hatchery. This dosage can be increased to at least 200 ppm in fully developed fingerlings, except in treating fish approximately 20 days old. Any treatment regime should therefore be flexible and should be adapted according to the age of the fish.

Description of Fish Production System Used in the Vaalharts Irrigation Scheme

The production of *Clarias gariepinus* in dams primarily used for irrigation by the farmers can be regarded as a combination of a pond culture system, flow-

through system and an integrated fish farming system. The reason for this classification is that the irrigation dam production differs from the usual pond production in that the water in the ponds is not stagnant with only top ups of water as water losses occur, but full water replacements occur on an approximately two weekly basis because of the irrigation of crops by the farmers. This production system is also integrated in the farming activities of the farmer, which results in a better utilization of water resources, an increase in income and the use of nitrogen enriched water for irrigation. The irrigation dams on average have a surface area of approximately 2500 m² with a depth of 1.5 m. The majority of dams in the area are lined with cement making them ideal for fish farming. The feeding of fish is initially by hand, three times a day and once the fish reach a size of 50 g, pendulum self-feeders are installed allowing the fish to feed *ad libitum*. Ultimately the effectiveness of any production system is determined by the growth rate of fish produced in the specific system.

Growth Rate

The performance of fish can be evaluated according to their growth rate or specific growth rate. Although both these growth parameters can be used, the specific growth rate of fish tends to give a clearer indication of fish growth. This statement is clearly illustrated if the specific growth rate (Figure 7) and growth rate (Figure 8) of fish in the irrigation dam are compared. The growth rate curve of these fish illustrates a continuous increase up to day 126 although the specific growth rate started decreasing after day 60 (Figures 7 and 8). From this illustration the conclusion can be made that the fish in the irrigation dam were increasing in weight but started growing more slowly after day 60. The evaluation of only the growth rate can therefore be misleading regarding the growth performance of fish. For this reason the growth performance of the fish stocked in the flow-through pond and irrigation dam were evaluated on the specific growth rates of the fish.

The highest specific growth rates recorded in the irrigation dam and flow-through pond were recorded during the months of January in the irrigation dam and December in the tarpaulin flow-through pond. The specific growth rate of *C. gariepinus*, as with other aquaculture species, is temperature dependant. Research has shown that optimum specific growth rates can be obtained at temperatures ranging from 27°C to 31°C (Hoogendoorn, Hansen, Koops, Machiels, van Ewijk and van Hees, 1983). The average water temperature in the irrigation dam and tarpaulin flow-through pond therefore never reached the optimum temperatures for maximum growth.

The fluctuating specific growth rate of fish in the flow-through pond indicates the shortcomings of this production system in providing optimal conditions for fish growth. Water replacement and stocking densities were optimal in the flow-through pond, therefore possible inadequacies of this system must be found elsewhere. Fish tend to crowd in this system under a small partially covered area of the pond. This behavioral response to daylight is normal for the nocturnally active feeding *C. gariepinus.* If an even distribution of fish throughout the pond is to be achieved, the whole pond must be covered. This will result in better utilization of the water volume in a pond. The flow-through ponds were also very shallow, not allowing the use of a pendulum self feeder. Deep narrow ponds, as used in recirculation systems seem to be a better design. This design will allow the introduction of a self feeder making it possible for the fish to feed at night when they are most active.

A typical decreasing specific growth curve can be expected in fish as they increase in weight. The bigger the fish gets the slower they grow. The specific growth rate of fish in the irrigation dam followed this typical curve, after an initial very low growth rate (Figure 7). The optimum specific growth rate of *C. gariepinus* at different temperatures has been determined in laboratory studies conducted by Hoogendoorn *et al.* (1983). If the presently measured specific growth rates of fish in the Vaalharts irrigation dam are compared to the experimentally determined specific growth rates at different temperatures as described by Hoogendoorn *et al.* (1983), the specific growth rate of fish

<200 g in the irrigation dam was considerably lower than that determined by the above mentioned authors (Figure 11).

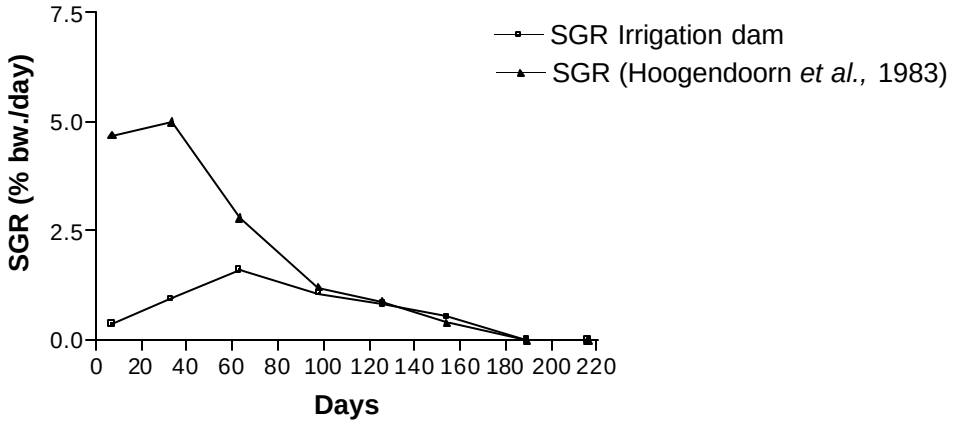

Figure 11. **The specific growth rates of *Clarias gariepinus* in the Vaalharts irrigation dam and estimated specific growth rates according to Hoogendoorn, Hansen, Koops, Machiels, van Ewijk and van Hees (1983), at the calculated average water temperature over the same period of time.**

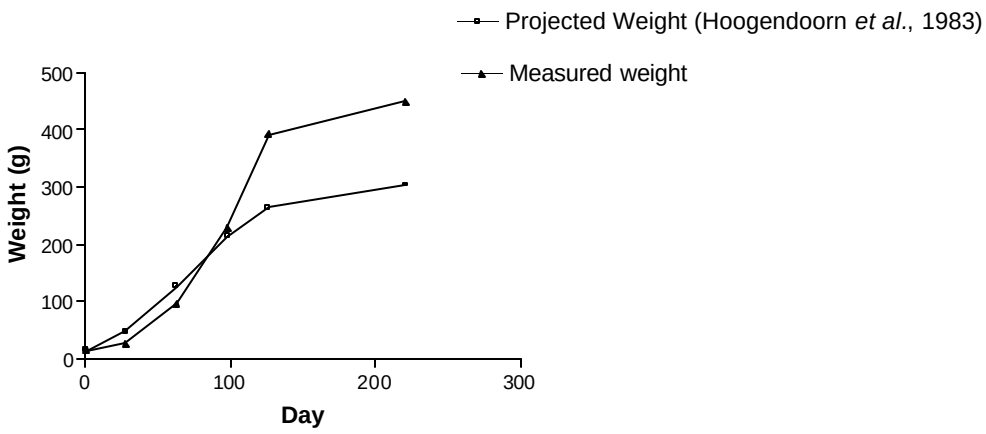

Figure 12. **A comparison between the projected weight according to specific growth rates of *Clarias gariepinus* experimentally determined by Hoogendoorn, Hansen, Koops, Machiels, van Ewijk and van Hees (1983), at different water temperatures and the measured weight of the fish in the Vaalharts irrigation dam.**

The difference between the experimentally determined growth rate of Hoogendoorn *et al*. (1983) and that measured for fish in the irrigation dam decreased as the fish increased in weight. If the measured weight of fish in the irrigation dam is compared to a projected theoretical weight of fish according to the above mentioned experimentally determined temperature dependant specific growth rates, the increase in growth rate is evident (Figure 12). If the specific growth rate of fish in both production systems were to be

critically evaluated, the initial specific growth rates in both production systems were far too low. After 100 days there was, however, a marked improvement in the specific growth rate of fish in the irrigation dam (Figure 11).

Since the same feed was used throughout the study and the fact that the problem occurred in both the production systems, nutrition and the type of production system used were disregarded as possible reasons for the problem. The remaining possible reasons for the low specific growth rates could be feed particle size and feeding regime.

Feed Particle Size

According to catfish feed manufactures Aquanutro (Pty) Ltd, the following feed particle sizes are recommended for the feeding fish according to their weight:

Fish weight (g)	Particle Size (mm)
<0.25	0.5
0.25 – 1.5	0.5 – 1.0
1.5 – 5.0	1.0 – 1.5
5.0 – 30	1.5 – 2.0
30 – 50	3.0
50 – 100	3.5
100 – 200	4
>200	6

Prior to stocking the irrigation dam, juvenile fish were fed feed manufactured by Aquanutro (Pty) Ltd, after stocking the fish in the irrigation dam they were fed extruded crushed 6 mm pellets by hand. Fish were fed the crushed pellets up to a size of 55.8 g at which time a pendulum self feeder was introduced supplying extruded 4 mm pellets. If the suboptimal growth rates of fish <200 g in the irrigation dam are considered and the fact that a feed particle size of 4 mm according to the feed manufactures must only be fed to fish >100 g, it is clear that the fish in the irrigation dam probably were fed feed with a too large particle size too early (Figure 12). It is therefore evident that although *C. gariepinus* is considered able to consume large feed types in

nature, the feeding of too large particle size feed too early in life can negatively affect the growth rate of fish in a production system.

Feeding Regimen

Clarias gariepinus can be regarded as a mobile sense organ with thousands of tactile, electric, taste, chemical and sound receptors scattered over the body. The eyes are relatively poorly developed and according to Bruton (1988), only appear to be able to detect movement and changes in illumination levels. *Clarias gariepinus* are primarily active during the night and are most efficient at capturing prey at low light levels (Bruton, 1979 a,b). The most natural time for feeding fish and maximum feeding by fish therefore will take place during the darkness of night. The growth rates of larvae were also found to increase with shorter light periods, the highest being recorded in continuous darkness (Britz and Pienaar, 1992). Feeding fish by hand during the night poses obvious practical problems. The only solution is the introduction of self feeders in a production system. If the increased growth rate of fish in the irrigation dam is considered after the introduction of a self feeder, this method of feeding is a must if optimum growth rates are to be achieved (Figure 13).

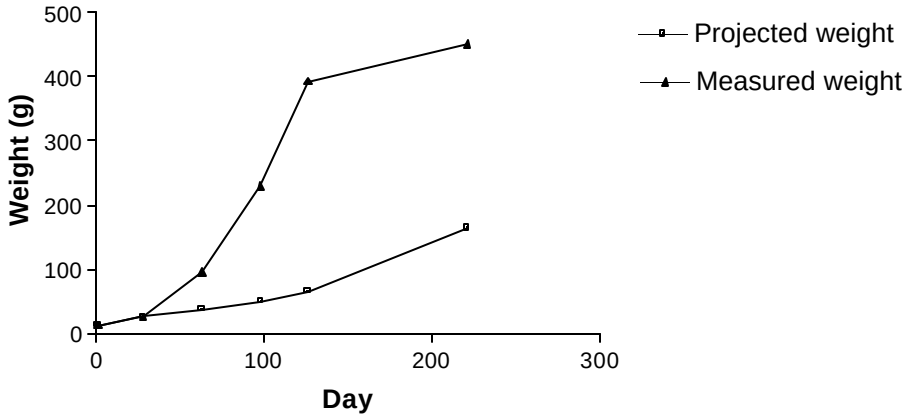

Figure 13. **A comparison between the measured weight of *Clarias gariepinus* in the Vaalharts irrigation dam and a projected weight based on the specific growth rate of fish prior to the introduction of the self feeder.**

CATFISH NUTRITION

3.1 INTRODUCTION

The dietary requirements of cultured fish are probably the most important factor influencing the success of any fish farming enterprise. The goal of any successful fish culture operation is to achieve maximum production of fish in the shortest time possible at the least cost. Since feeding represents the single most expensive production cost, the use of optimal performance dry feeds is essential. Dry feeds, especially in respect of juvenile fish, can also be supplemented with live zooplankton as a food source. It is recommended that dry feeds are used as primary food source for larvae and that live food must be presented once a day (Uys, 1988). Zooplankton is, therefore, a very important food source for juvenile fish upon initial stocking in an irrigation dam.

The optimal use of dry feeds and live feed will result in good feed conversion rates (FCR) and growth rates. Consequently the FCR and growth rate of fish fed a specific dry feed can be regarded as criteria for feed evaluation. The FCR of any production animal can be defined as the weight of feed consumed to produce a specific weight unit of body mass. For example, if 2 kg of feed were fed to an animal to produce 1 kg of body mass, the FCR would be 2. The FCRs of different production animals differ considerably. A FCR of 8.5 would be considered as very good for feedlot cattle, 2.5 for pigs and 1.8 for broiler chickens. The best FCRs are, however, found in fish, feed conversion rates of up to 1.05 have been observed experimentally in *Clarias gariepinus* (Uys, 1988). The FCR of *C. gariepinus* is dependent on the nutritional value of the specific dry feed consumed. *Clarias gariepinus* is classified as an opportunistic omnivore. This is reflected by the high levels of various enzymes, pancreatic amylase, gastric lysozyme and gastric and pancreatic protease found in this species that facilitate the digestion of different dietary components (Uys and Hecht, 1987). Although *C. gariepinus* is classified as an

omnivore, its intestine is simple, thin walled and relatively short, implying a dependence on protein-rich food. This is reflected in studies done where the best feed conversion and growth rates have been achieved with diets consisting of 38% to 42% crude protein (Uys, 1988). High protein feeds must, however, contain the right, mostly animal protein derived, essential amino acids for optimum growth.

If the above mentioned factors are taken in consideration, the importance of determining the FCR and nutritional value of feed mixtures intended for use in a production system cannot be over emphasized. Since there are not many commercial feeds locally available for catfish, any prospective farmer must be content with the feeds available in his area. Fortunately the majority of the smaller feed manufacturers will manufacture a feed according to the user's specifications if large enough orders are placed. It was therefore decided to produce a catfish feed according to an existing recipe that has in the past been used by Roy Kannemeyer. This feed was subsequently evaluated and compared to that of a commercially available dry feed. Unfortunately the recipe for the commercially available 33% protein dry feed could not be disclosed because of reasons of confidentiality.
The objectives of this study were:

- To determine the nutritional value of two feed mixtures (local recipe vs. commercial feed),
- To determine the FCR and growth rates of two feeds (local recipe vs. commercial feed) fed to fish in flow-through ponds in the Vaalharts Irrigation Scheme, and
- To determine the zooplankton numbers in the Vaalharts irrigation dams.

3.2 MATERIAL AND METHODS

Feed Analysis

Two feed mixtures, one commercially available of which the manufacturers did not disclose the composition and one local recipe containing 12% fishmeal, 20% soybean meal, 10% blood meal, 8% calories 3000, 35% wheat bran, 10% maize bran, 4% alphalpha meal and 1% vitamin premix were pelleted by extrusion. The extruded feed pellets were sent to ARC – Irene Analytical Services, Private Bag X2, Irene, 0062 for analysis.

Samples were analyzed for:
Protein, fat, calcium, phosphorous, arginine, serine, aspartic acid, glutamic acid, glycine, threonine, alarine, tyrosine, proline, HO- proline, methionine, valine, phenylalanine, isoleucine, leucine, histidine, lysine, tryptophan and energy.

Feed Conversion and Growth Rates

After the nutritional analyses of the two feeds were completed, the feed conversion rate (FCR) and growth rate (GR) for both feeds were determined over a period of 23 days.

Juvenile *Clarias gariepinus* were weighed, counted and placed in two 1 m^3 tarpaulin flow-through ponds. Fish were fed three times a day and observations were made daily regarding feed acceptability and possible cannibalism. The feed consumption, total study population and weight of the fish in each pond were recorded at the start and end of the 23 day study period. In addition to this, weekly samples of fish were netted, counted and weighed to calculate a weekly estimated FCR.

The FCR and GR were calculated using the following formulae:

$$FCR = \frac{TF}{TWG}$$

Where TF = Total feed consumed over the test period.

TWG = Total weight gained by the fish over the test period.

$$GR = \frac{EW - SW}{LD - FD}$$

Where EW = Measured average end weight of fish over the test period.
SW = Measured average start weight of fish.
LD = Last day of test period.
FD = First day of test period.

Natural Feeds

The occurrence of zooplankton in the Vaalharts irrigation dam used as the grow out pond was determined monthly from May 2004 to December 2004. The irrigation dam used for grow out had little aquatic vegetation. Therefore, additionally from May to August the occurrence of zooplankton in an irrigation dam with a lot of aquatic vegetation was sampled for comparison to determine the influence of vegetation on zooplankton numbers. Five ~50 ml samples were taken during each assessment by dragging a 15 cm diameter funnel-shaped net with a screw on collection bottle at the bottom point, 15 m in the dam, sampling a total water volume of 1.32 m^3. The 5 samples of ~50 ml where subsequently pooled and water was added to form one sample with a volume of 600 ml. The 600 ml sample was then placed on a magnetic stirrer to distribute the zooplankton evenly throughout the mixture. A 20 ml sub-sample was taken and the zooplankton was counted in the sub-sample using a stereomicroscope. Zooplankton were counted according to the following groupings, namely: representatives of the Cladocera, Copepoda, Ostracoda and Rotifera, as well as insect larvae. The total number of zooplankton per 600 ml sample was calculated by multiplying the count in the 20 ml by 30. The volume of water sampled was calculated using the following formula:

Total Volume (m^3) sampled = [? r^2 x Dd (m)] x 5

Where r = Radius in m of net opening.

Dd = The distance that the net was dragged.

3.3 RESULTS

Feed Analysis

The percentage protein in the local recipe feed and the commercial feed were 22.07% and 33.50% respectively (Table 1). The 22% protein feed had, however, more fat (4.66%) and energy (18.31 kj/g) than the 33% protein feed (Table 1). If the essential amino acids were to be calculated as g/100g protein, the local recipe feed had proportionally more arginine, isoleucine, leucine, lysine, phenylalanine + tyrosine, threonine and valine than the commercial feed (Table 2).

Table 1. Analysis of two feed mixtures provided by ARC – Irene Analytical Services.

	Commercial feed	Local recipe feed	Unit
Protein	33.5	22.07	%
Fat (ether extraction)	2.47	4.66	%
Calcium	1.8	1.22	%
Phosphorous	0.77	0.88	%
Serine	1.11	0.88	g/100g feed
Aspartic acid	1.94	1.42	g/100g feed
Glutamic acid	3.09	2.61	g/100g feed
Glycine	0.99	1.32	g/100g feed
Alanine	1.04	1.1	g/100g feed
Tyrosine	1.46	1.16	g/100g feed
Proline	1.06	1.2	g/100g feed
HO-Proline	0.14	0.31	g/100g feed
Arginine	1.57	1.42	g/100g feed
Histidine	1.15	0.73	g/100g feed
Isoleucine	1.08	0.85	g/100g feed
Leucine	1.57	1.43	g/100g feed
Lysine	1.79	1.49	g/100g feed
Methionine	0.4	0.38	g/100g feed

Phenylaline	1	0.82	g/100g feed
Threonine	0.8	1.03	g/100g feed
Tryptophan	0.55	0.27	g/100g feed
Valine	1.08	0.97	g/100g feed
Energy	18.01	18.31	kj/g

Table 2. The essential amino acids [as specified by Fagbenro and Jauncey (1995) for *Clarias gariepinus*] composition (g/100g protein) of the commercial feed (33% protein) and local recipe feed (22% protein).

	Commercial feed	Local recipe feed
Arginine	4.7	6.4
Histidine	3.4	3.3
Isoleucine	3.2	3.9
Leucine	4.7	6.5
Lysine	5.4	6.7
Phenylalanine + Tyrosine	7.4	9.0
Threonine	2.4	4.7
Tryptophan	1.6	1.2
Valine	3.2	4.4

Feed Conversion and Growth Rates

22% Protein Local Recipe Feed

The mean feed conversion rates (FCR) of fish fed the 22% protein local recipe feed varied between 3.72 (25 Nov 2004) and 1.47 (17 Dec 2004). The FCR calculated at the end of the study when all the fish were counted and weighed, was 1.56 (Table 3). Mortalities of the fish fed the 22% protein feed were 43 (1.56%) during the study period. Feed acceptability was initially low, but improved after the first week. The low initial feed acceptability resulted in observed cannibalism.

33% Protein Commercial Feed

The mean feed conversion rates of fish varied between 1.39 (25 Nov 2005) and 0.65 (01 Dec 2005). The FCR calculated at the end of the study when all the fish were counted and weighed, was 1.27. Mortalities at the end of the

study period were 148 (6.4%) (Table 3). Feed acceptability was, as with the 22% protein feed initially low, but improved after the first week. Cannibalism was also observed during the first two weeks of the study.

Table 3. **The weekly and total feed conversion rates (FCR) and growth rates calculated for the fish fed the 22% protein local recipe feed and the 33% protein commercial feed.**

Local recipe feed (22% protein) - n=2760								
Date	**Feed (kg)**	**Sample (n)**	**Weight (g)**	**Avg. Weight (g)**	**Avg. Gain (g)**	**Pond Gain (kg)**	**Growth rate (g/day)**	**FCR**
19/11/2004		2760	48355.2	17.52				
25/11/2004	7.6	53	968	18.26	0.74	2.04	0.12	3.72
01/12/ 2004	6.44	50	1000	20.00	1.74	4.79	0.29	1.34
09/12/2004	11.18	50	1182	23.64	3.64	10.05	0.46	1.11
17/12/2004	11.21	64	1690	26.41	2.77	7.63	0.40	1.47
Total	36.43	2717	71751	26.41	8.89	23.39	0.31	1.56

Commercial feed (33% protein) - n=2316								
Date	**Feed (kg)**	**Sample (n)**	**Weight (g)**	**Avg. Weight (g)**	**Avg. Gain (g)**	**Pond Gain (kg)**	**Growth rate (g/day)**	**FCR**
19/11/2004		2316	40576.32	17.52				
25/11/2004	7.07	56	1084	19.36	1.84	5.08	0.31	1.39
01/12/2004	6.67	52	1200	23.08	3.72	10.27	0.62	0.65
09/12/2004	12.03	50	1426	28.52	5.44	15.02	0.68	0.80
17/12/2004	11.28	60	1932	32.20	3.68	10.16	0.53	1.11
Total	37.05	2168	69838	32.21	14.68	29.26	0.52	1.27

Natural Feed in Dams

Except during August when more representatives of the Cladocera were found in the irrigation dam with no aquatic vegetation, the monthly total numbers of zooplankton in the irrigation dam with aquatic vegetation were greater than in the dam with no aquatic vegetation (Table 4). The highest cladoceran counts in the grow out irrigation dam were recorded during the winter months of May to July with the highest count in July (Table 5). Total copepod counts ranged between 0 (June) and 330 (September) in the grow

out irrigation dam. Insect larvae were only found during the months July and October. No ostracods and rotifers were found (Table 5).

Table 4. **A comparison between the invertebrate counts in the 20 ml aliquot and the calculated total zooplankton in the 600 ml sample from May 2004 to August 2004 between irrigation dams with a lot of aquatic vegetation and no aquatic vegetation.**

Zooplankton											
Irrigation dam	**Month**	**Clad***	**Tot**	**Cope***	**Tot**	**Ins***	**Tot**	**Ostr***	**Tot**	**Roti***	**Tot**
Vegetation	May	28	840	0	0	16	480	0	0	0	0
No vegetation	May	11	330	2	60	0	0	0	0	0	0
Vegetation	Jun	32	960	9	270	4	120	0	0	1	30
No vegetation	Jun	3	90	0	0	0	0	0	0	0	0
Vegetation	Jul	207	6210	29	870	4	120	1	30	0	0
No vegetation	Jul	12	360	6	180	1	30	0	0	0	0
Vegetation	Aug	3	90	6	180	0	0	1	30	1	30
No vegetation	Aug	4	120	3	90	0	0	0	0	0	0

* Clad = Representatives of the Cladocera; Cope = Representatives of the Copepoda; Ins = Insect larvae; Ostr = Representatives of the Ostracoda; Roti = Representatives of the Rotifera; Tot = total

Table 5. **The zooplankton counts in the 20 ml aliquot and the calculated total zooplankton in the 600 ml sample in the irrigation dam used for the catfish grow out from May 2004 to December 2004.**

Zooplankton											
Pond	**Month**	**Clad***	**Total**	**Cope***	**Total**	**Ins***	**Total**	**Ostr***	**Total**	**Roti***	**Total**
Irrigation dam	May	11	330	2	60	0	0	0	0	0	0
Irrigation dam	Jun	3	90	0	0	0	0	0	0	0	0
Irrigation dam	Jul	12	360	6	180	1	30	0	0	0	0
Irrigation dam	Aug	4	120	3	90	0	0	0	0	0	0
Irrigation dam	Sep	1	30	11	330	0	0	0	0	0	0
Irrigation dam	Oct	0	0	2	60	1	30	0	0	0	0
Irrigation dam	Nov	2	60	3	90	0	0	0	0	0	0
Irrigation dam	Dec	6	180	5	150	0	0	0	0	0	0

* Clad = Representatives of the Cladocera; Cope = Representatives of the Copepoda; Ins = Insect larvae; Ostr = Representatives of the Ostracoda; Roti = Representatives of the Rotifera

Table 6. **The total zooplankton population at each sample time point in the irrigation dams with little and a lot of aquatic vegetation.**

	Cladocerans		**Copepods**		**Insect larvae**		**Ostracods**		**Rotifes**	
Pond	Total *	Total **	Total *	Total **	Total *	Total **	Total *	Total **	Total *	Total **
Vegetation	840	1590910	0	0	480	909091	0	0	0	0
No vegetation	330	625000	60	113636	0	0	0	0	0	0
Vegetation	960	1818182	270	511364	120	227273	0	0	30	56818

No vegetation	90	170455	0	0	0	0	0	0	0	0
Vegetation	6210	11761367	870	1647728	120	227273	30	56818	0	0
No vegetation	360	681818	180	340909	30	56818	0	0	0	0
Vegetation	90	170455	180	340909	0	0	30	56818	30	56818
No vegetation	120	227273	90	170455	0	0	0	0	0	0

* = (1.32 m³)

** = (2 500 m³)

Total volumes of 1.32 m³ water in each of the irrigation dams were sampled at each time point. The estimated average total volume of the irrigation dams is 2 500 m³. The total counts in Tables 4 and 5 were only a fraction of the zooplankton population in each dam. Table 6 summarizes the total estimated zooplankton populations in the irrigation dams with a little and a lot of aquatic vegetation.

3.4 DISCUSSION

The calculated percentage protein of the local recipe feed was ~35% before extrusion. The results obtained from the feed analysis show, however, that this relatively high protein level had been lowered to 22.07% after extrusion (Table 1). The decrease in the crude protein contents during pelleting is probably a result of the heat generated by the extrusion process. It is therefore important to analyze a feed after extrusion and not the feed mixture before extrusion if an accurate result is to be obtained.

Table 7. The recommended optimal composition for a *Clarias gariepinus* production feed [taken from Uys (1988)].

Dietary requirements	
Crude protein	38-40%
Total lipid	>8%
Digestible energy	12 kj/g
Calcium	1.5%
Phosphorus	0.5%

Although *Clarias gariepinus* is regarded as an omnivorous fish, it still has a relatively high dietary protein requirement. According to Uys (1988), the best

feed conversion rates and growth rates are achieved with a diet consisting of 38 to 42% crude protein and an energy level of 12 kj/g.

The dietary requirements of *C. gariepinus* as specified by Uys (1988) are summarized in Table 7. The energy content of the commercial feed and the local recipe were 18.01 kj/g and 18.31 kj/g respectively (Table 1). Both the feeds therefore had sufficient energy content, but the protein levels were too low. The Calcium content of the commercial feed was sufficient, but the local recipe lacked the required amount of this specific nutrient (Tables 1 and 7). Both feeds had sufficient phosphorus nutrients (Tables 1 and 7). Although the protein levels of both feeds were insufficient for optimum feed conversion and growth rates, the test feeds did meet the essential amino acid (EAA) requirements (g/100g protein) as described by Fagbenro and Jauncey (1995) (Table 8).

Table 8. **The essential amino acid (EAA, g/100g) requirements as taken from Fagbenro and Jauncey (1995), for *Clarias gariepinus* and the essential amino acid composition of the commercial feed (33% protein) and local recipe feed (22% protein).**

	EAA requirements	Commercial feed	Local recipe feed
Arginine	4.3	4.7	6.4
Histidine	1.5	3.4	3.3
Isoleucine	2.6	3.2	3.9
Leucine	3.5	4.7	6.5
Lysine	5	5.4	6.7
Phenylalanine + Tyrosine	5	7.4	9.0
Threonine	2	2.4	4.7
Tryptophan	0.5	1.6	1.2
Valine	3	3.2	4.4

These EAA requirements are, however, based on the requirements of channel catfish (*Ictalurus punctatus*) and not *Clarias gariepinus.* Studies done on the EAA requirements of *Clarias gariepinus* indicate that it requires a minimum of 4.5 g/100g dietary protein arginine and 1.1 g/100g tryptophan (Fagbenro, Nwanna and Adebayo, 1999; Fagbenro, 1999). Generally, if lysine and sulphur amino acid requirements are met, other amino acids will be adequate if feed stuffs commonly used in fish feeds are used (Robinson and Lowell,

1984). Lysine is found in the highest concentrations in fish meal, blood meal and fish offal. Therefore low lysine levels could indicate an insufficient amount of animal derived protein especially fish derived proteins in the feed.

It is evident that the higher protein levels of the commercial feed consisted to a large extent of cheaper plant derived proteins. According to Uys (1988), *C. gariepinus* diets require at least 12% fishmeal to meet the above mentioned requirements. According to Machiels (1987), a decrease in weight gain with an increase of fishmeal being replaced by an alternative protein source was observed in *C. gariepinus*. This could be the result of various factors for example lower digestibility. The lower acceptability and higher mortalities as a result of cannibalism of the commercial feed in comparison to those of the local feed recipe also suggest that feeds containing proportionally too low animal derived proteins, may lower the palatability of the feed. This low palatability explains the higher incidence of cannibalism found in fish fed the commercial feed. It is therefore evident that the amino acid profile is very important in any feed and that the profile must agree with that of fish meal (Machiels, 1987).

Just as too little protein can be detrimental to growth, too much of certain nutrients can also be detrimental to fish growth. Studies have shown that diets containing >22% fat will reduce feed intake and subsequently weight gain. This reduction in feed intake is caused by the rapidly increasing fat percentage in fish biomass as a result of the high dietary fat levels. *Clarias gariepinus* regulates its feed intake by the fat content of its biomass. A fat fish will eat less than a leaner fish of the same weight. A higher energy diet will therefore increase the fat content of the fish and the fish will react to this by eating less (Machiels and Henken, 1987).

Environmental factors may also play a role in the nutrient requirements of *C. gariepinus*. The requirements of *C. gariepinus* with respect to crude protein are comparable to other omnivorous fish species, which are greater at higher temperatures. At saturation levels of feeding, consumption of lower protein

diets will be increased at higher water temperatures and may satisfy higher protein requirements at these elevated temperatures (Henken, Machiels, Dekker and Hoogendoorn, 1986). This phenomenon could economically justify the use of higher protein feeds at higher temperatures to reduce feed intake. This topic, however, needs further investigation to validate the potential use of different protein feeds at different water temperatures in the Vaalharts Irrigation Scheme.

The feed conversion rates of the two test feeds were directly proportional to their protein levels. The highest protein feed (commercial feed = 33%) had the best FCR of 1.27 followed by the local recipe feed (22%) with a FCR of 1.56. These feed conversion rates could, however, have been improved if the percentage of protein in the test feeds had been increased to the optimum level of 38 – 42% for *C. gariepinus* as found by Uys (1988). The highest percentage gain in body weight was also obtained from the fish fed with 33% commercial feed. This percentage gain of 83.79% was 33.05% higher than that of the 22% protein local recipe feed. This higher percentage gain is clearly evident in the higher average daily growth rate of 0.51 g/day in comparison with a 0.31 g/day growth rate of the fish fed the 22% protein local recipe feed (Table 3).

The correct feed formulation is therefore the most important factor influencing the production of catfish. High protein diets will result in optimal production, but optimal production feeds will not always result in economic optima. To achieve maximum profit the economic optimum must be established for a feed, although the feed formulation for both optima will, however, seldom be the same (Machiels, 1987).

When farming with *C. gariepinus* it is very important to first establish the FCR of the feed that you will be using in a controlled study. After establishing the FCR, this can be used as a very important tool in the management of the

farm. The FCR could for example be used to calculate pond gain based on feed consumption (Table 9). If samples of fish are netted and average weight is calculated, the percentage mortalities of fish in the pond could also be estimated (see Chapter 2, Production). All these figures obtained from the FCR play a very important role in the management of any fish farm.

Table 9. A comparison between calculated average weight of fish in the grow out dam based on a feed conversion rate of 1.2 and the average measured weight of fish samples netted.

Date	n	Feed weight	Pond gain	Individual gain	Average weight	Measured weight
25/11/2004	94	22.10	18.34	1.09	9.99	14.17
23/12/2004	151	293.73	243.80	14.53	23.43	26.30
27/01/2004	41	799.50	663.59	39.56	62.99	95.95
03/03/2005	43	1975.00	1639.25	97.71	160.70	229.60
31/03/2005	37	1835.00	1523.05	90.79	251.49	391.90
28/04/2005	37	1400.00	1162.00	69.27	320.76	554.00
02/06/2005	50	200.00	166.00	9.90	330.65	480.00
29/06/2005	150	30.00	24.90	1.48	332.13	450.00

The predominant zooplankton in the ponds belonged to the groups Cladocera and Copepoda. There were significantly more ($p<0.05$) of these organisms in ponds with plentiful aquatic vegetation. The highest zooplankton counts were recorded during winter and not in the summer months, as one would expect. The prediction of zooplankton numbers in the irrigation dams in the Vaalharts Irrigation Scheme is very difficult. Because of the irrigation of crops, zooplankton is lost through water replacement in the dams. This results in large fluctuations in zooplankton numbers depending on the time of sampling.

The nutrient composition of zooplankton is excellent for fingerling and larval growth and it is therefore a very important component of the diet of fingerlings stocked in the dams. Upon initial stocking fingerlings largely depend on zooplankton as their main food source until they can comfortably consume the

4 mm floating extruded feed pellets (Uys, 1988). It is therefore important to monitor zooplankton numbers in ponds prior to stocking. Since the dam containing a lot of vegetation had a lot more zooplankton, the stocking of fish in such dams could hold great advantages for a farmer. If the zooplankton numbers are insufficient, ponds could be enriched with organic fertilizer to stimulate population growth of zooplankton. The nutrient composition of zooplankton is summarized below in Table 10.

Table 10. Nutrient composition (dry matter basis) of zooplankton according to Robinson and Lowell (1984), collected from channel catfish ponds in the Mississippi Delta.

Nutrient Composition (Dry Matter Basis)	
Dry Matter	7.7
Crude Protein	72.5
Crude Fat	6.2
Crude Fiber	10.7
Nitrogen-free Extract	8.1
Ash	2.6
Amino Acids (5 Protein)	
Arginine	7.1
Histidine	3.0
Isoleucine	4.1
Leucine	7.3
Lysine	6.8
Methionine	2.3
Cystine	1.1
Phenylalanine	3.9
Tyrosine	6.1
Threonine	4.5
Tryptophan	0.9
Valine	4.6
Alanine	8.0
Aspartic Acid	7.9
Glutamic Acid	12.3
Glysine	4.8
Proline	4.3
Serine	4.1

CATFISH DISEASE

4.1 INTRODUCTION

Disease is one of the most important factors influencing the success of fish culture. Disease in fish is the result of an interaction between at least three factors: host susceptibility, pathogen virulence and suboptimal environmental conditions. Diseases of fish often occur as secondary infections following stress due to suboptimal environmental conditions such as poor water quality, nutritional deficiency and crowding. The main causes of disease can be summarized as: water quality deficiencies, bacterial and viral infections, protozoan parasites, fungal infections, monogenetic trematodes, digenetic trematodes, cestodes, nematodes and crustacean parasites.

Considerable attention has been given to the study of parasites of South African inland freshwater fishes, in particular cichlid fishes. Very little attention has, however, been paid to the parasite fauna of the African sharptooth catfish, *Clarias gariepinus,* especially in aquaculture (van As and Basson, 1988). Disease in *C. gariepinus* has been recorded in the wild or in production systems as a result of all the main causes listed above. *Clarias gariepinus* does not harbour any more or any fewer parasites than other fish species, at least not in the wild (van As and Basson, 1988).

Fish have inborn protective mechanisms that come into action when something abnormal interferes with them. For example anti-microbial components of the blood serve to eliminate bacteria, but some of these substances are not produced during cold weather, and during prolonged periods of cool weather fish become highly susceptible to infections (Rogers, 1971). The pathogens associated with *C. gariepinus* seldom cause mortalities in the wild. However, in the “unnatural” environment of a high-density production system often associated with stressed fish, these pathogens are potentially deadly.

In order to farm successfully with catfish (*C. gariepinus*) in the Vaalharts Irrigation Scheme, a study *in loco* of the occurrence of fish disease (parasitic and non parasitic) is necessary. Since the aquatic environment in a production system has an influence on virtually every important disease affecting fish, both the environment and the disease must be studied. The study of disease in *C. gariepinus* therefore necessitates the study of not only the prevalence of disease in the study area and production system, but also of the quality of the water in which they occur. The best method of controlling disease in fish is prevention, and this can only be achieved through relevant research on the diseases that are potentially present. The objectives of this study were:

- To record the prevalence of fish parasites and possible non-parasitic disease on and in *C. gariepinus* and other fish species present in the irrigation dams,
- To monitor the water quality of the irrigation dam, and
- Since preliminary samples of fish indicated that monogenean and trichodinid parasites were the most prevalent in the study area, the effect of seasonal temperature fluctuations on these parasites were investigated in a laboratory study.

4.2 MATERIAL AND METHODS

Parasites

Samples were collected over a period of 11 consecutive months by netting fish from the tarpaulin hatchery ponds and the irrigation dam. Skin scrapings were performed on all fish netted by scraping along the lateral aspects of the body and the fins with a glass microscope slide and transferring the collected material to a clean slide. The collected material was examined under a stereomicroscope for parasites. The gills of the fish were removed and also

examined under a stereo microscope. The presence of internal parasites was determined by examining muscle tissue and the body cavities. A number of digestive tracts collected from fish in the irrigation dams were examined for parasites, but because no parasites were found initially, this exercise was not continued. Any parasites found were identified, at least to genus level, and the host and date recorded. Any other clinical symptoms observed incidentally by Roy Kannemeyer or Des Puttick in fish in the Vaalharts hatchery ponds and irrigation dam were also recorded.

Water Quality

To determine the water quality of the irrigation dams, two monthly samples of water were collected from the irrigation dam for analysis. Water samples collected were analyzed by the Institute of Ground Water Studies (IGS, University of the Free State, Bloemfontein campus) using standard water analysis methods. Inductively coupled plasma optical emission spectroscopy (ICP – OES) was used to analyze samples for Ca, Mg, Na, K, Al, As, Cr, Cu, Fe, Mn, Pb and Zn. Ion chromatography was used to analyze samples for Cl, SO_4, NO_3, N, F, Br and PO_4. In addition to this, the pH of each sample was measured by means of a pH meter.

Effect of Temperature on Monogenean and Trichodinid Parasites

Two hundred juvenile *C. gariepinus* were collected from a population of fish with a high confirmed incidence of monogenean and trichodinid infestations within the hatchery. The fish were randomly assigned to experimental groups of 100 fish each. The experimental groups were maintained at two temperature regimes in aerated containers. One group was kept at a high water temperature (25 - 30°C) and the other at a low temperature (10 - 15°C). Fish were fed a commercially available fish feed daily. After an acclimatization period of four days the examination of fish for parasites was initiated. Daily

from Monday to Friday over a period of 12 days three fish from each experimental group were euthanazed and examined for parasitic infestations. The body region examined and parasite count for each fish was standardized to a skin scraping of only one side of the fish and the gill arches of only one set of gills. The gill arches and material collected from the skin scraping was examined under a stereo microscope. All parasites found on each fish were identified to genus level, counted and recorded. If no parasites were found on a specific fish, the rest of the fish were examined for parasites to prevent false negative results.

4.3 RESULTS

The Prevalence of Fish Parasites and Possible Non-Parasitic Diseases on and in *Clarias gariepinus* and Other Fish Species in the Irrigation Dams.

A total of 53 fish were dissected from April 2004 to February 2005. Parasites found on the fish examined were: *Trichodina* spp., *Gyrodactylus* spp., *Dactylogyrus* spp., *Ichthyophthirius multifiliis* and *Ichtyobodo necator* (Table 1 and Figure 1). The prevalence of fish infested with trichodinids, monogeneans and *Ichthyophthirius multifiliis* were:

Trichodina spp.	:	75%
Gyrodactylus spp.	:	9.4%
Dactylogyrus spp.	:	47.2%
Ichthyophthirius multifiliis	:	17.0%

Table 1. The prevalence of parasite groups on the skin and/or gills of the 53 fish dissected from April 2004 to February 2005 in the study area.

	Percentage (%) prevalence

Species dissected	n	*Trichodina* spp.	*Dactylogyrus* spp.	*Gyrodactylus* spp.	*Ichthyophthirius multifiliis*	*Ichtyobodo necator*
Clarias gariepinus	32	75%	56.25%	6.25%	18.75%	0%
Tilapia sparrmanii	12	66.67%	41.67%	25%	25%	16.67%
Pseudocrenilabrus philander	3	100%	0%	0%	33.34%	33.34%
Gambusia affinis	2	100%	0%	0%	0%	0%
Cyprinus carpio	3	66.67%	66.67%	0%	0%	66.67%

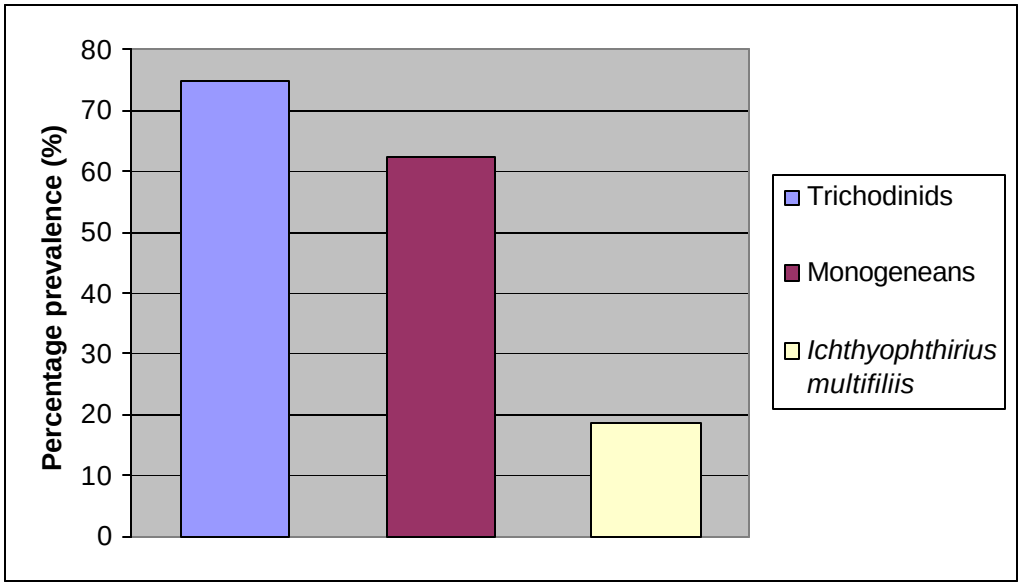

Figure 1. **The percentage prevalence of parasitic groups found on the skin and gills of *Clarias gariepinus* in the Vaalharts area.**

Of the total of 32 *C. gariepinus* specimens dissected and examined, 99.9% were host to one or more parasite species.

Cursory periodic inspections of fish in the hatchery ponds and irrigation dam were made. The symptoms observed and recorded are summarized in Table 2. These symptoms included red swollen abdomens, grey patches and cottony mass on the skin and physical injuries (Figures 2, 3, 4 and 5).

Table 2. **Symptoms recorded during cursory inspections of Vaalharts hatchery ponds and irrigation dam.**

Symptom observed	Possible disease associated with symptom
Red swollen abdomen	Ruptured intestine syndrome
Grey patches on skin of fish (Figure 2)	Bacterial infection
Cottony mass on skin of fish (Figure 3)	Fungal infection
Broken backs (Figure 4)	Bird predation
Loss of tail (Figure 5)	Bird predation

Figure 2. **A photograph of suspected bite wounds and grayish patches on the skin of a catfish (*Clarias gariepinus*) found in one of the tarpaulin ponds in the Vaalharts hatchery.**

Figure 3. **A cottony mass on the skin of a juvenile catfish (*Clarias gariepinus*) in the Vaalharts hatchery.**

Figure 4. **A photograph of a catfish (*Clarias gariepinus*) with a broken back netted in the Vaalharts irrigation dam.**

Figure 5. **Photographs of catfish (*Clarias gariepinus*) with severed tails netted in the Vaalharts irrigation dam.**

Water Quality

The results of the water analysis done every two months are summarized in Table 3. Heavy metals exceeding the acceptable levels for fish culture were: Al, Cu, Mn and Zn. The total unionized ammonia levels in the irrigation dam were also calculated using the total ammonia measured at a specific pH and the average calculated temperature for that specific month (Tables 4 and 5).

Table 3. **Water quality analysis of water taken every two months from the Vaalharts irrigation dam.**

Month	$CaCO_3$	pH	NO_3	TDS	Al	As	Cu	Fe	Mn	Pb	Zn
	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Mg/l
June	109	9.42	<0.199	665	0.015	<0.010	0.013	0.014	0.006	<0.015	0.005
August	128	8.40	0.93	560	0.117	<0.010	0.018	0.065	0.008	<0.015	0.012
October	166	7.81	18.15	758	0.056	<0.010	0.007	0.030	0.003	<0.015	0.011
December	122	7.24	<0.199	614	0.027	<0.010	0.024	0.037	0.004	<0.015	0.013
February	124.5	6.45	<0.199	647	0.041	<0.010	0.014	0.049	0.026	<0.015	0.022
April	112	7.67	<0.199	475	0.026	<0.010	0.037	0.047	0.028	<0.015	0.014
Acceptable levels	20-200	-	<50	<400	< 0.1	<0.7	<0.006	<0.1	<0.01	<0.02	<0.005
Maximum	166	9.42	19.69837	787	0.117	<0.010	0.037	0.065	0.028	<0.015	0.047
Minimum	109	6.45	0.75	354	0.015	<0.010	0.007	0.014	0.003	<0.015	0.005

Table 4. **Percentage of the total ammonia nitrogen taken from Noga (2000) that is present as unionized ammonia at various temperature and pH combinations in fresh water.**

Temperature (°C)	PH								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0	0.00827	0.0261	0.0826	0.261	0.820	2.55	7.64	20.7	45.3

1	0.00899	0.0284	0.0898	0.284	0.891	2.77	8.25	22.1	47.3
2	0.00977	0.0309	0.0977	0.308	0.968	3.00	8.90	23.6	49.4
3	0.0106	0.0336	0.106	0.335	1.05	3.25	9.60	25.1	51.5
4	0.0115	0.0364	0.115	0.353	1.14	3.52	10.3	26.7	53.5
5	0.0125	0.0395	0.125	0.394	1.23	3.80	11.1	28.3	55.6
6	0.0136	0.0429	0.135	0.427	1.34	4.11	11.9	30.0	57.6
7	0.0147	0.0464	0.147	0.462	1.45	4.44	12.8	31.7	59.5
8	0.0159	0.0503	0.159	0.501	1.57	4.79	13.7	33.5	61.4
9	0.0172	0.0544	0.172	0.542	1.69	5.16	14.7	35.3	63.3
10	0.0186	0.0589	0.186	0.586	1.83	5.56	15.7	37.1	65.1
11	0.0201	0.0637	0.201	0.633	1.97	5.99	16.8	38.9	66.8
12	0.0218	0.0688	0.217	0.684	2.13	6.44	17.9	40.8	68.5
13	0.0235	0.0743	0.235	0.738	2.30	6.92	19.0	42.6	70.2
14	0.0254	0.0802	0.253	0.796	2.48	7.43	20.2	44.5	71.7
15	0.0274	0.0865	0.273	0.859	2.67	7.97	21.5	46.4	73.3
16	0.0295	0.0933	0.294	0.925	2.87	8.54	22.8	48.3	74.7
17	0.0318	0.101	0.317	0.996	3.08	9.14	24.1	50.2	76.1
18	0.0343	0.108	0.342	1.07	3.31	9.78	25.5	52.0	77.4
19	0.0369	0.117	0.368	1.15	3.56	10.5	27.0	53.9	78.7
20	0.0397	0.125	0.396	1.24	3.82	11.2	28.4	55.7	79.9
21	0.0427	0.135	0.425	1.33	4.10	11.9	29.9	57.5	81.0
22	0.0459	0.145	0.457	1.43	4.39	12.7	31.5	59.2	82.1
23	0.0493	0.156	0.491	1.54	4.70	13.5	33.0	60.9	83.2
24	0.0530	0.167	0.527	1.65	5.03	14.4	34.6	62.6	84.1
25	0.0569	0.180	0.566	1.77	5.38	15.3	36.3	64.3	85.1
26	0.0610	0.193	0.607	1.89	5.75	16.2	37.9	65.9	85.9
27	0.0654	0.207	0.651	2.03	6.15	17.2	39.6	67.4	86.8
28	0.0701	0.221	0.697	2.17	6.56	18.2	41.2	68.9	87.5
29	0.0752	0.237	0.747	2.32	7.00	19.2	42.9	70.4	88.3
30	0.0805	0.254	0.799	2.48	7.46	20.3	44.6	71.8	89.0

Table 5. The total unionized ammonia levels in the Vaalharts irrigation dam after stocking.

Month	Ammonia as N (mg/l)	pH	Average Temperature (°C)	Percentage unionized ammonia (%)	Unionized Ammonia (mg/l)
October	0.31	7.81	20.12	3.82	0.011842
December	0.324	7.24	25.24	0.566	0.001834
February	0.162	6.45	25.28	0.18	0.000292
April	0.303	7.67	20.16	1.24	0.003757

Influence of Temperature on Skin and Gill Trichodinid and Monogenean Infestations.

Trichodinids belonging to *Trichodina heterodentata* and *T. maritinkae* were found on the skin and gills of juvenile *C. gariepinus* (Figure 6). There was a reduction in the mean number of trichodinids on the skin of the group exposed to the high water temperature (Table 6 and Figure 8). No distinct pattern of

reduction was found in counts of trichodinids found on the skin of the group exposed to a low water temperature (Table 6 and Figure 8). A reduction in mean monogenean numbers found on the skin of fish was recorded in both experimental groups (Table 7 and Figures 7 and 9).

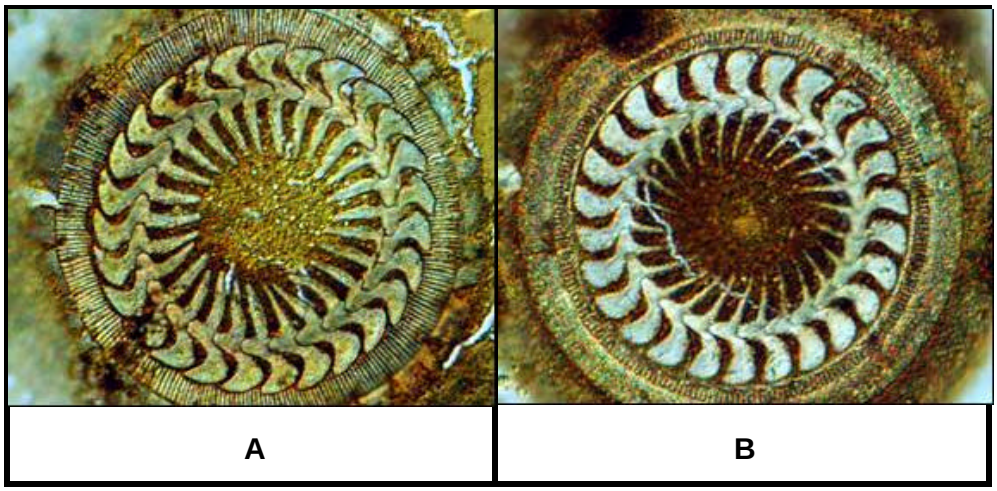

Figure 6. **A photograph of the two trichodinids species, *Trichodina heterodentata* (A) and *Trichodina maritinkae* (B) found on *Clarias gariepinus*.**

Figure 7. **A photograph of a monogenean found on *Clarias gariepinus*.**

Table 6. **The total number of trichodinids per fish counted on the skin during each of the assessment days in the groups exposed to the low water temperature (10 – 15 °C) and high water temperature (25 – 30 °C).**

	Total trichodinids per skin scraping					
Day	High temperature			Low temperature		
	Specimen 1	Specimen 2	Specimen 3	Specimen 1	Specimen 2	Specimen 3
1	150	9	8	1	1	3
2	71	31	9	24	10	4
3	14	10	9	14	18	11
4	0	1	9	0	6	1
5	6	14	1	10	23	17
8	0	0	1	23	39	144
9	0	0	0	9	6	19
10	0	0	0	8	3	0
11	0	0	0	2	1	5
12	0	0	1	35	0	0
Total	241	65	38	126	107	204
Average	114.67			145.67		

Table 7. **The total number of monogeneans per fish counted on the skin during each of the assessment days in the groups exposed to the low water temperature (10 – 15 °C) and high water temperature (25 – 30 °C).**

	Total monogeneans per skin scraping					
Day	High temperature			Low temperature		
	Specimen 1	Specimen 2	Specimen 3	Specimen 1	Specimen 2	Specimen 3
1	1	5	0	0	0	3
2	5	2	1	12	0	4
3	1	1	0	1	10	0
4	0	0	1	1	0	3
5	1	2	0	8	16	10
8	0	0	0	4	0	4
9	0	0	0	0	0	0
10	0	0	0	0	2	0
11	0	0	0	0	0	1
12	0	0	0	0	0	0
Total	8	10	2	26	28	25
Average	6.67			26.33		

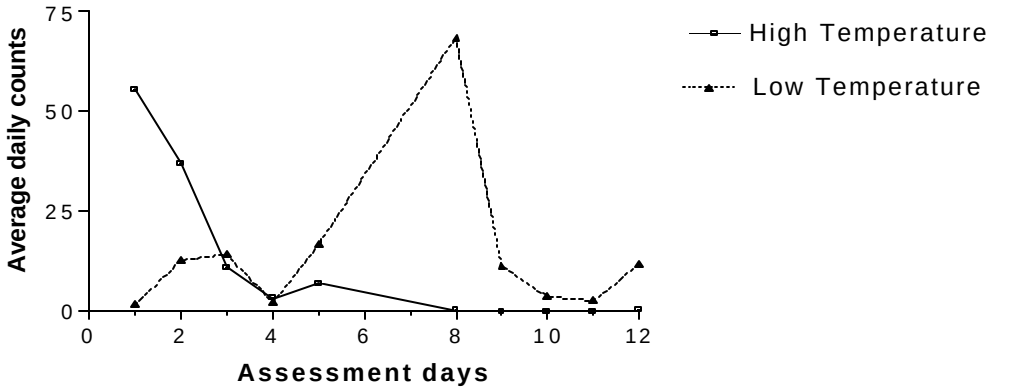

Figure 8. **A graphic illustration of the average number of trichodinids counted daily on the skin of the three *Clarias gariepinus* specimens over a twelve day period.**

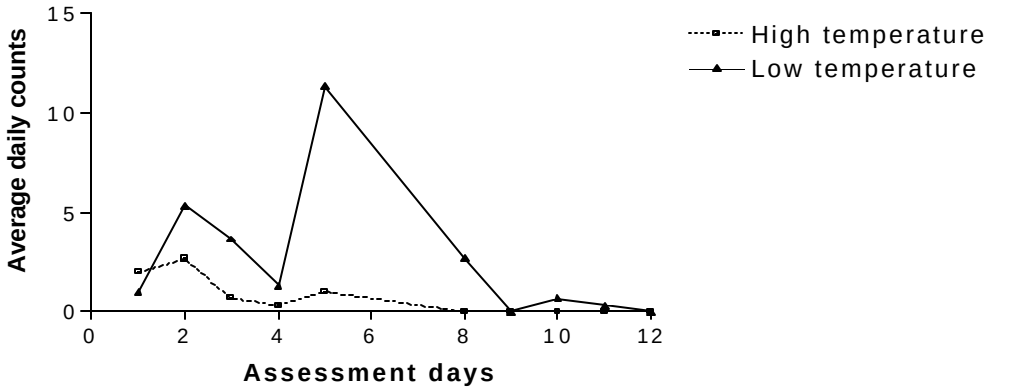

Figure 9. **A graphic illustration of the average number of monogeneans counted daily on the skin of the three *Clarias gariepinus* specimens over a twelve day period.**

An increase in the mean number of trichodinids found on the gills was recorded in the group exposed to the low water temperature. This contrasted with the group exposed to a high water temperature where a decrease in the mean trichodinids counted was recorded (Table 8 and Figure 10). There was a reduction in the mean number of monogeneans found on the gills of both test groups (Table 9 and Figure 11).

Table 8. **The total number of trichodinids per fish counted on the gills during each of the assessment days in the groups exposed to the low water temperature (10 – 15 °C) and high water temperature (25 – 30 °C).**

	Total trichodinids on the gills					
Day	High temperature			Low temperature		
	Specimen 1	Specimen 2	Specimen 3	Specimen 1	Specimen 2	Specimen 3

1	60	9	10	2	24	4
2	15	38	72	4	16	2
3	14	49	15	3	2	6
4	4	1	4	9	8	1
5	29	22	11	9	143	2
8	2	3	4	93	12	33
9	0	0	2	1	5	60
10	0	0	3	21	45	13
11	5	14	7	39	23	34
12	10	6	0	35	11	12
Total	139	142	128	216	289	167
Average	136.33			224		

Table 9. **The total number of monogeneans per fish counted on the gills during each of the assessment days in the groups exposed to the low water temperature (10 – 15 °C) and high water temperature (25 – 30 °C).**

	Total monogeneans on the gills					
Day	**High temperature**			**Low temperature**		
	Specimen 1	**Specimen 2**	**Specimen 3**	**Specimen 1**	**Specimen 2**	**Specimen 3**
1	8	29	18	50	2	59
2	56	45	29	30	5	6
3	18	22	24	2	21	7
4	15	19	13	27	10	4
5	28	37	9	18	16	7
8	6	2	19	25	9	7
9	1	4	6	21	19	34
10	2	10	13	42	6	3
11	7	11	4	21	1	5
12	5	5	6	13	15	39
Total	146	184	141	249	104	171
Average	157			174.67		

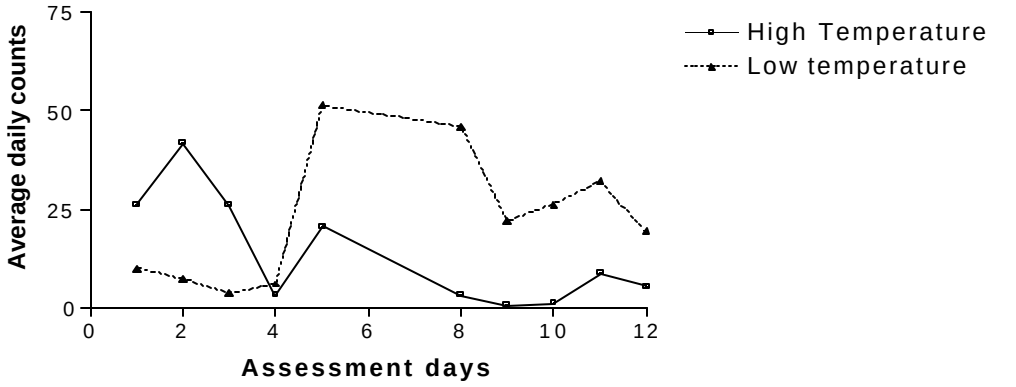

Figure 10. **A graphic illustration of the average number of trichodinids counted daily on the gills of the three *Clarias gariepinus* specimens over a twelve day period.**

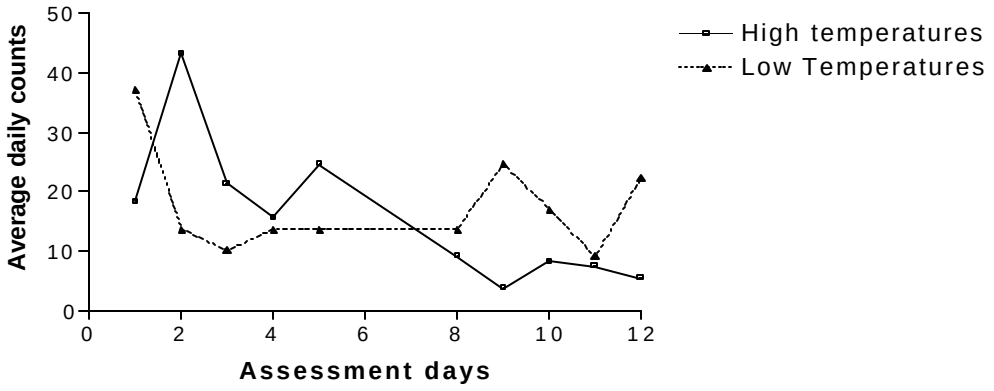

Figure 11. **A graphic illustration of the average number of monogeneans counted daily on the gills of the three *Clarias gariepinus* specimens over a twelve day period.**

4.4 DISCUSSION

WATER QUALITY

Ammonia Poisoning

Ammonia is the principal nitrogenous waste released by fish and also originates from decay of complex nitrogenous compounds (e.g. protein) (Figure 12). Ammonia is mainly excreted via the gills of fish as ammonia gas. As a by-product from the digestion of proteins an estimated 1 kg of ammonia nitrogen is produced from every 45 kg of feed fed (Losordo, Masser and Rakocy, 1998). Bacteria in the water convert ammonia to nitrite (NO_2-) and nitrite to nitrate (NO_3-). Ammonia in water exists as two compounds, e.g. ionized (NO_{2+}) and unionized (NH_3) ammonia. Of these two the unionized form of ammonia is extremely toxic to fish. The unionized ammonia levels present in water depends on pH and temperature and can be calculated from the total ammonia measured at a specific water temperature and pH (Noga, 2000) (Table 5). The unionized ammonia in the irrigation dam was calculated for the months October, December, February and April using Table 4 and the average water temperatures and pH measured for that specific month.

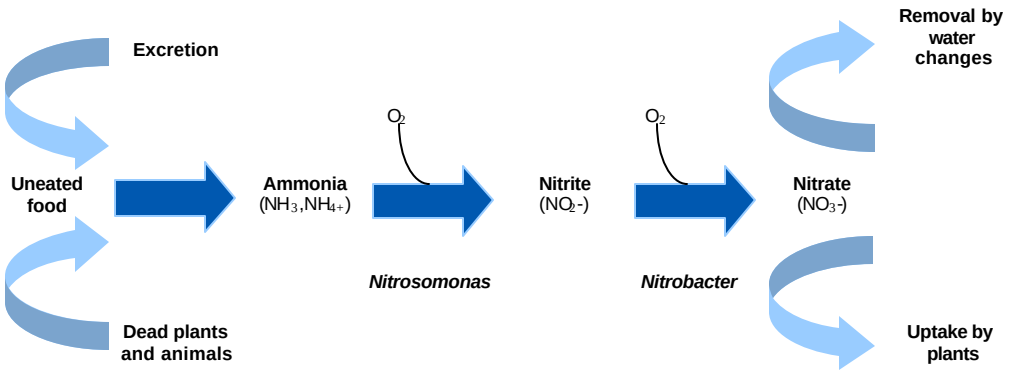

Figure 12. A diagrammatic representation of the nitrogen cycle adapted from Noga (2000).

The highest unionized ammonia levels were recorded during October (0.012 mg/l) and April (0.004 mg/l) in the irrigation dam. According to Noga (2000) ammonia tends to increase during autumn and winter, possibly because of a decrease in algal and bacterial metabolism at low temperatures, supporting the finding in the irrigation dam. Ammonia poisoning is also most likely to occur near sunset, when pH, temperature and thus unionized ammonia (UIA) are at their peaks (Noga, 2000). At a lethal poisoning concentration of ~1.00 mg UIA/l and sub-lethal poisoning of ~0.05 mg/l the unionized ammonia concentrations in the irrigation dam were well below the lethal and sub-lethal concentrations (Table 5). As illustrated by Figure 12, ammonia can be removed from a pond by being assimilated by plants or by the removal of the water. Due to the high-volume irrigation regimen followed by farmers in the Vaalharts Irrigation Scheme, high water replacements are the norm in the irrigation dams. This high level of water replacement in the irrigation dams will regulate ammonia build-up.

Water Hardness as $CaCO_3$

Water hardness requirements vary greatly between fish species, but a total hardness of at least 50 mg/l is recommended for most warm water food fish (e.g. channel catfish, *Ictalurus punctatus*) (Noga, 2000). The water hardness measured as $CaCO_3$ in the irrigation dam varied between 109 mg/l and 166

mg/l from June 2004 to April 2005 thus remaining within the acceptable range of 20 mg/l – 200 mg/l (Table 3).

Metal Poisoning

Fish are very sensitive to aqueous metals, which is why water that is regarded safe for human consumption can be highly toxic to fish. According to Noga (2000), dissolved metals may be introduced in ponds through:

- Metal plumbing,
- Ground water, especially soft, acidic water may have toxic concentrations of metals,
- Overdosing with copper algaecide or ectoparasiticides, and
- Rain water run-off from poorly buffered soils.

Clinical signs of metal poisoning vary between elements and fish species, but as with most toxins signs are mostly non-specific. The most common cause of metal poisoning is copper. Copper is a common pollutant in surface waters and its toxicity is largely attributable to its cupric (Cu^{2+}) form (Olaifa, Olaifa and Onwude, 2004). Copper compounds are used for prophylactic purposes to control fish disease and parasites as well as the control of algae, slugs and snails in irrigation water systems (Olaifa *et al*., 2004 and Perschbacher, 2005).

Water samples from the irrigation dams have shown continuously high levels of this metal in the irrigation dam that are above general acceptable levels for fish culture (Table 3). These elevated levels of copper may be acutely or chronically toxic to the fish in the irrigation dams. While unlikely, acute effects may result in death. The more likely chronic effects may include reduced growth, shorter life span, reproductive problems, reduced fertility and behavioral changes (Olaifa *et al*., 2004). According to Olaifa *et al*. (2004) the 96 hour LC50 concentration of copper for juvenile *C. gariepinus* is 0.67 mg/l, which is much higher than the highest level of copper (0.037 mg/l) found in the irrigation dams (Table 3). Although the occurrence of metal poisoning in the

irrigation dam is highly unlikely, elevated levels of Cu must be taken into consideration before using algaecides or ectoparasiticides containing this metal, which may, in combination with copper already in the water, exceed the levels that the catfish in the dams can tolerate.

Temperature Effects on Monogenean and Trichodinid Parasite Infestations

The most economically important monogeneans in fish culture are members of the Superfamilies Gyrodactyloidea and Dactylogyroidea. Members of the Superfamily Gyrodactyloidea are viviparous, and are pathogenic to a wide range of freshwater and marine fish species. Members of the Superfamily Dactylogyroidea are oviparous and are primarily found on the gills of their freshwater fish hosts (Noga, 2000). Severe monogenean infestations can be indicators of poor water quality as parasites rapidly reproduce under these conditions (Noga, 2000).

The reproduction rate of monogeneans is temperature dependent, which may result in seasonal fluctuations in their population density. No significant differences were found in the average number of monogeneans counted on the gills of the groups of *C. gariepinus* exposed to the low (10 - 15°C) and high (25 - 30°C) water temperatures over the 12 day study period (Table 9). A reduction in the numbers of monogenean parasites found on the skin was, however, found in both groups (Table 7). According to Paperna (1980) the infestation levels of dactylogyrid monogeneans in different fish species seems to be determined by the inter-relationship between the parasites and their specific hosts, while environmental parameters and other factors are apparently of secondary importance. This pattern was also evident from the results obtained in the current study and the reduction and subsequent disappearance of monogenean parasites were similar to that reported by Paperna (1980) in *Tilapia* sp.

Trichodinid parasites infest the skin and/or gills of marine and freshwater fish. In general the larger (>90 um) skin dwelling trichodinids have a broader host range than the smaller (<30 um) gill dwelling trichodinids (van As and Basson, 1987). Trichodinids were found throughout the year on the skin and gills of *C. gariepinus* fingerlings in the study area. A reduction in the average number of trichodinids counted on the skin and gills of *C. gariepinus* were found in the fish exposed to a high (25 - 30°C) water temperature (Figures 8 and 10). This contrasted to the fish exposed to a low water temperature, where an increase of trichodinids on the skin and gills was found (Figures 8 and 10).

Figure 13. A photograph of debilitated anorexic juvenile *Clarias gariepinus* netted in the Vaalharts hatchery.

According to Noga (2000) trichodinid infestations are present mainly in fish that are debilitated because of some other condition, e.g. poor nutrition or overcrowding. These debilitated anorexic fish were often observed in the Vaalharts hatchery (Figures 13 and 14). If it is taken into consideration that *C. gariepinus* is regarded as a warm water species, low water temperatures can potentially debilitate fish. This seems to be the case in the laboratory test where increases of trichodinids were only found in the fish exposed to low water temperatures. The results also indicate a strong possibility for seasonal fluctuations in trichodinid infestations with an increase in winter. Field studies

are, however, needed to support the hypothesis of the possible occurrence of seasonality in trichodinid infestations on *C. gariepinus* in the Vaalharts Irrigation Scheme.

Figure 14. A photograph of a debilitated anorexic *Clarias gariepinus* netted in the Vaalharts irrigation dam

Viral and Bacterial Diseases

Diseased fish are the end result of an interaction between at least three factors: host susceptibility, pathogen virulence and environmental factors (Bragg, 1988). No major losses due to viral or bacterial infections were identified during the 12-month observation period. Studies have shown that *C. gariepinus* is disease resistant and are not affected by the viral diseases affecting channel catfish (*Ictalurus punctatus*) in North America (Boon, McDowell and Hedrick, 1988).

Swollen red abdomens resulting in mortalities of fingerlings were observed in the Vaalharts hatchery ponds. According to Huisman and Richter (1987) these symptoms are typical of a viral infection causing the rupture of the caudal part of the intestine that have resulted in up to 70% mortalities of fingerlings.

Mortalities associated with this symptom in the Vaalharts hatchery ponds was very low and of no great concern to the farmers. Fingerlings displaying the above mentioned symptoms were also dissected to determine the possibility of internal parasite infection, but no internal parasites could be found.

The occurrence of red swollen abdomens and ruptured intestines in juvenile catfish is therefore likely to have been caused by a virus associated with this condition. This disease affects young fish 3 – 5 g at an age of 5 – 8 weeks when they are fed at a high level. Gross symptoms of this disease are: discolored swollen belly, red anus and hemorrhagic smelly fluid in the abdominal cavity (Boon, Oorschot, Henken and van Doesum, 1987). According to Hariati, Machiels, Verdegem and Boon (1994), feed type, feed quantity and timing of presentation influences the prevalence of ruptured intestine syndrome. The feeding of live feeds such as *Artemia nauplhi* translated into lower levels of mortality than feeding dry feeds. The highest percentage survival was recorded by the above-mentioned authors when levels of dry feed were kept low and natural feeds were used.

Grayish lesions and patches on fish suffering from bite marks were also observed indicating a possible bacterial infection (Table 2). According to Rogers (1971) there are three main types of bacteria affecting channel catfish (*Ictalurus punctatus*) in North America, namely Columnaris, *Aeromonas* and *Pseudomonas*. A common symptom of Columnaris infection is frayed fins and grayish lesions or patches on the skin similar to those observed in fish in the Vaalharts hatchery.

Aeromonas and *Pseudomonas* lesions may be small grayish patches similar to those of Columnaris, but more often there are bloody patches and extensive erosions of the tissue (Roger, 1971). *Aeromonas*, which is ubiquitous in all fresh water environments, probably cause the most common bacterial disease of fresh water fish (Noga, 2000). According to Noga (2000) the risk of infection increases considerably following damage to the integument of the skin. If the above-mentioned factors are taken into

consideration, the lesions observed on *C. gariepinus* in the Vaalharts hatchery are most likely caused by either one of the two bacterial infections.

Protozoan Parasites

A variety of protozoan parasites are associated with fresh water fishes and have been implicated in disease and mortalities. Of all the protozoan parasites present in the study area only *Ichthyophthirius multifiliis* and *Trichodina* sp. were found on *C. gariepinus* (Figures 6 and 15). Major losses due to *I. multifiliis* infestations were recorded in one Vaalharts hatchery flow-through pond during the month of May 2004. Infestations of *I. multifiliis* were, however, confined to one hatchery dam emphasizing the importance of an independent pond flow-through system and not a single flow-through linking all hatchery ponds. Losses recorded were >90%, but were reduced after applying a formalin treatment regimen (see Chapter 5, Disease treatment). Of the 51 fish dissected 75% were infested by trichodinids on the gills or skin or both (Table 1). The percentage infestation prevalence on *C. gariepinus* was 77%, but no specific mortalities could be attributed to trichodinids.

Trichodinosis is usually a relatively mild disease that can cause chronic morbidity or possible mortality. Heavily infested fish are anorexic, lose condition, but usually only experience a low level of mortality of 1% per week (Noga, 2000). Protozoan parasites therefore pose no great risk to catfish culture in the study area with the exception of *I. multifiliis*. White spot disease, caused by *I. multifiliis* infestations, is one of the most common diseases of freshwater fish and scaleless fish like catfish are especially vulnerable (Noga, 2000). Mortalities of fish in the study area were confined to the hatchery and no mortalities were found in the grow out irrigation dam.

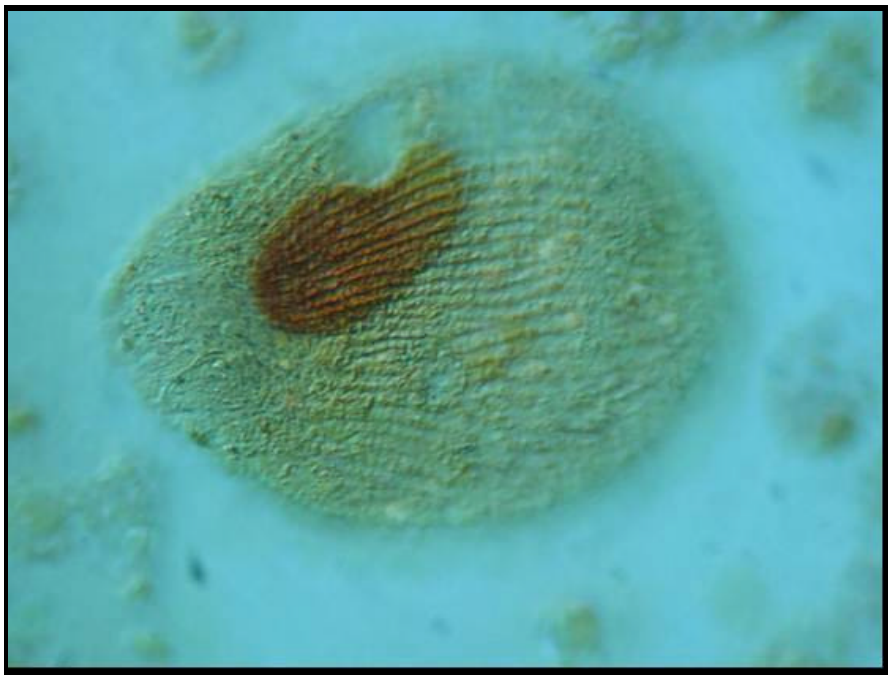

Figure 15. A photograph of Ichthyophthirius multifiliis found on Clarias gariepinus.

Fungal Infections

Water moulds (Class Oomycetes) are by far the most common fungal infections of freshwater fish. The ubiquitous opportunistic fungi of the genus *Saprolegnia* are commonly found on the skin of adults, larvae and ova of *Clarias gariepinus* raised in aquariums (van As *et al*., 1988). A white cottony mass infecting injured skin of larvae was occasionally observed in *C. gariepinus* fingerlings in the hatchery (Table 2). No healthy fish were, however, infected. According to van As *et al.* (1988) many cases of *Saprolegnia* infections appeared shortly after the collection and transport of *C. gariepinus*. This may be the result of injuries sustained during the handling process. The observations made at the hatchery and those made by van As and Basson (1988) indicate that opportunistic fungal infections are mostly secondary infections in immuno-suppressed fish. Factors that may lead to a higher incidence of infections are:

- Sudden drop in water temperatures,

- Skin wounds caused by mechanical trauma or pathogens,
- Crowding, and
- High organic loads in the water.

All of the above factors are, however, controlled through good management of the aquaculture environment, thus reducing the risk of *Saprolegnia* infections considerably.

Monogenic Trematodes

Severe mortalities of fingerlings due to monogenean infestations have been reported by the Department of Ichthyology and Fisheries Science, Rhodes University, emphasizing the importance of controlling these infestations in fingerlings (van As and Basson, 1988). A prophylactic treatment plan was followed in the Vaalharts hatchery ponds and fingerlings were treated every two weeks. Monogeneans have been found to survive formalin bath treatments at dosages of up to 200 ppm on *C. gariepinus* fingerlings (see Chapter 5, Disease treatment). The failure to eradicate this monogenean parasite from the hatchery may be the result of re-infestations from the environment or the use of too low formalin dosages.

It is evident from the results obtained from this study that the treatment regimen followed only controlled and did not eradicate the monogenean population and only reduced mortalities due to hyper infestations. According to Noga (2000), eggs of some monogeneans are resistant to treatment. An important consideration is therefore whether the monogenean is viviparous or oviparous. In the hatchery the occurrence of the oviparous dactylogyrid monogeneans was 45% higher than that of viviparous gyrodactylid monogeneans. The difference in prevalence of dactylogyrid and gyrodactylid monogeneans after treatment indicated the possible survival of dactylogyrid monogeneans because their eggs were resistant to treatment. Although the treatment regimen followed at the hatchery did not eradicate the monogenean parasites, it definitely reduced the number of parasites infesting fish because

no mass mortalities were observed in fingerlings as a direct result of monogenean infestations. It is evident, however, that *C. gariepinus* fingerlings are much more sensitive to monogenean infestations than larger individuals where infestations seem to have no detrimental effect on the fish.

Digenetic Trematodes

Trematodes are transmitted to fish by snails and a number of trematode metacecariae have been reported to infect *Clarias gariepinus* in the wild (Mashego, 1977; van As and Basson, 1984). No digenetic trematodes were found in any of the dissected fish collected from the Vaalharts irrigation dam and as yet no digenetic trematodes have been found in cultured *C. gariepinus* (van As and Basson, 1988). The risk of digenetic trematode infections in cultured *C. gariepinus* seems to be low, but definitely possible. Good management under conditions of culture can easily prevent the introduction and spread of digenetic trematodes by eliminating the snail intermediate hosts or by measures taken to scare off piscivorous birds. If it is taken into consideration that humans can be infected if infected fish is eaten raw, the above mentioned preventive management practices must be implemented in any *C. gariepinus* farm that is seriously considering the export of fish.

Cestodes

A variety of tapeworms are parasitic in freshwater fish but because their life cycles are complex and require one or two intermediate hosts, tapeworms are relatively uncommon in cultured fish. Adult and larval tapeworms can infect fish with adult infection always occurring in the intestine. Tapeworm species of the genus *Ligula* and *Bothriocephalus* may potentially infect fish with the latter genus causing a serious problem amongst carp at the Lowveld Fisheries Research station (Brandt, Schoonbee and van As, 1980). To control larval cestodes under culture conditions, it is best to break the life cycle by ensuring that the final host, the piscivorous bird, cannot come into contact with fish. As

no tapeworms were, however, found in fish slaughtered for marketing in the Vaalharts Irrigation Scheme, the risk of tapeworm infections in the area seems to be fairly low.

Nematodes

Nematode infections in *C. gariepinus* under natural conditions are very common and have been reported by Prudhoe and Hussey (1977) as well as by Mashego and Saayman (1980). During surveys done by van As and Basson (1988) every catfish examined in the Northern Province had an infection of larval *Contracaecum* attached to the viscera. Fish are infected with these larvae by ingesting other infected fish. Ingested larvae subsequently migrate from the stomach to the viscera where their numbers can accumulate should the specific fish constantly feed on infected fish. *Clarias gariepinus* are carnivorous and regularly feed on other fish. The control of nematode infections in cultured fish therefore necessitates the eradication of other prey fish from the ponds. This can be done through the use of filter screens at the water in-flow point or the use of fish specific lethal treatments that kill only target fish species (Treves-Brown, 2000). It is also necessary to incorporate the inspection of fish during processing as a standard management practice in processing facilities to reduce the risk of infected fish reaching the market and consequently possibly harming consumer confidence. No nematodes were found in fish slaughtered for marketing in the Vaalharts Irrigation Scheme, and the risk of nematode infections in the area therefore seems to be fairly low.

Crustaceans

Under natural conditions, *C. gariepinus* can host crustaceans like the branchiuras, *Argulus, Chonopeltus* and *Dolops* as well as copepods like *Ergasilus* and *Lamproglena* (van As and Basson, 1988). No crustaceans could, however, be found on *C. gariepinus* collected from the Vaalharts

hatchery ponds or irrigation dam. Small fish tend to clean one another effectively thus explaining the absence of this parasite in the hatchery (van As and Basson, 1988). Research done on *Argulus japonicus* has shown some form of an immunological response that prevents hyperinfestations with this parasite in *C. gariepinus* (van As and Basson, 1988). Crustacean infestations seem therefore to pose no real threat to *C. gariepinus* culture.

DISEASE TREATMENT

5.1 INTRODUCTION

Disease is universally accepted as one of the major threats to commercial aquaculture. The successful treatment of diseased fish is therefore one of the most important aspects influencing the success of any aquaculture enterprise. Diseased fish in a fish production system can only practically be treated through the medication of the water in the ponds or by in-feed medication. Fish can be treated by medicating the water using a number of methods, namely:

- **Immersion or Dipping**

  This method prepares a relatively small volume of medicated water in a separate container from that of the holding pond. The fish are then netted in the holding pond and immersed in the medicated water for a short period of time after which they are returned to their normal environment (Treves-Brown, 2000).

- **Flushing**

  This method can be used where fish are kept in running water, which is not re-circulated, for example in raceways. Immersion is achieved by shutting off the flow, medicating the water and after an appropriate interval, restarting the flow, thus removing the medicated water. The effect is a rapid rise in drug concentration in the water, followed by a slow fall (Treves-Brown, 2000).

- **Bath Treatment**

  Where large numbers of fish are kept in one pond or cage, dipping becomes impractical and the bathing technique must be resorted to.

Bathing differs from dipping in that fish are kept in the water that they are living in. In bathing the volume of water that must be medicated is reduced by decreasing the water levels in the ponds. This reduces the amount of drug required, the cost and environmental contamination. After medication of the water, the fish are exposed for a maximum of 60 minutes after which the water volume is restored to its normal level (Treves-Brown, 2000).

- **Submerged bags or Baskets**

  The control of bacteria and transmissible stages of parasites can be achieved by hanging bags or baskets of simple disinfectants in the water (Treves-Brown, 2000).

Water medication has the advantage in that it is adaptable to mass medication of large numbers of fish. Furthermore, unlike mass in-feed medication it does not depend on fish feeding, so it can be applied to non-feeding fish. However, in-feed medication is a much less wasteful method of administration than water medication. Medication can be added to feeds by:

- **Pelleted Medicated Feeds**

  The medicinal product is added to the feed mixture prior to pelleting. However, pelleting involves high temperatures and hence pellets can only be medicated with heat-stable compounds (Treves-Brown, 2000).

- **Surface Coated Pelleted Feed**

  This method involves the mixing of pellets and the medicinal product with a binding agent, which is usually gelatin or an edible oil such as sunflower oil or cod liver oil (Treves-Brown, 2000).

Before attempting to administer any medication, the effective dosage and safety of the specific substance must be known. Little efficacy and safety

information is available for commonly used aquaculture pharmaceuticals for *Clarias gariepinus*.

During the study period various parasites were encountered on juvenile *Clarias gariepinus* reared at the hatchery in the Vaalharts Irrigation Scheme (see Chapter 4, Catfish Disease). The prevalence of these parasites in juvenile *C. gariepinus* raised in the Vaalharts hatchery presented an opportunity to evaluate the effectiveness of some drugs commonly used by the farmers. One such opportunity occurred during May 2004 with an outbreak of white–spot disease (*Ichthyophthirius multifiliis*) in one of the hatchery ponds. Mortalities of juvenile fish in the infested pond were very high and it was apparent that the majority of fish were infested. After consultation with Des Puttick and Roy Kannemeyer it was decided to compare and evaluate the effectiveness of a formalin bath treatment with prolonged formalin treatment. According to Treves-Brown (2000), a dilution of 1:6000 or 167 ppm formalin is commonly used in aquaculture for 30-60 minute bath treatments. Formalin dosages of 15 ppm – 25 ppm for 24 hours can also be used for prolonged immersion to treat diseased fish (Noga, 2000). Taking the weakened state of the diseased fish and the cold water temperatures that lengthen the life cycle of *I. multifiliis* into consideration, it was decided to treat the fish with minimum formalin dosages at weekly intervals.

Despite the prophylactic treatment of ponds with formalin by the farmers the prevalence of trichodinid and monogenean infestations in juvenile *C. gariepinus* raised in the Vaalharts hatchery were very high. It was therefore decided to evaluate the effectiveness of one hour long formalin bath treatments at dosages of 250 ppm and 500 ppm against infestations with the above mentioned parasites.

It is important to note that tests conducted and discussed by the author in this chapter must not be regarded as clinically designed efficacy studies, but only as exploratory exercises giving possible indications of efficacy and safety that could be used as justification for larger studies. The main objective of this

chapter is to provide prospective *C. gariepinus* farmers with a general overview of treatments that could possibly be used for diseased fish.

5.2 MATERIAL AND METHODS

The fish infested with *I. multifiliis* were separated into three groups consisting of an untreated control group (Group1, n = 1540) and two treatment groups (Groups 2 and 3, n = 600). This was done by randomly removing and counting two sets of 600 fish each from the infested pond and placing them in two previously unused ponds. The remaining fish in the infested pond were also moved to an unused pond where they served as an untreated control group. The study population size of the control group was only determined at the conclusion of the study by adding the total recorded mortalities to the number of remaining living fish in the pond. The fish in the different experimental groups were kept in tarpaulin flow-through ponds ranging in water volume from 1.5 to 2 m^3. The ponds had a constant through-flow of water with ~12 full water replacements a day.

It was decided to treat the fish in the two treatment groups at weekly intervals with an ~15 ppm 24 hour prolonged formalin treatment and a one hour ~100 ppm formalin bath, respectively. The two treatment groups were therefore treated as follows:

Group 2 : Two 24 hour ~15 ppm formalin flush exposures one week apart.

Group 3 : Two one hour ~100 ppm formalin bath exposures one week apart.

In experimental Group 2, receiving the flush treatment, the water flow was stopped and 30 ml of formalin was added to a calculated pond volume of 1 890 liter of water, resulting in a 16 ppm formalin concentration. The water flow was only opened after 24 hours of exposure, thus removing the

medicated water. In experimental Group 3, receiving the bath treatment, the water level in the pond was decreased until a calculated 315 liter of water remained. A volume of 35 ml formalin was subsequently added resulting in a formalin concentration of 111 ppm, slightly higher than initially planned. The fish were exposed to this treatment for one hour after which the water flow was re-opened.

After the first treatment the daily mortalities of fish were recorded in each group. The following experimental schedule was followed:

Day 0	:	Treat Groups 2 and 3.
Day 0 to +6	:	Record mortalities in Groups 1 to 3.
Day +7	:	Treat Group 2 and 3.
Day +7 to +14	:	Record mortalities in Groups 1 to 3.

The daily percentage mortalities and total percentage survival was subsequently calculated using the following formulas:

$$\text{Daily percentage mortality} = \frac{TD}{TS} \times 100$$

Where TD = Daily total number of dead fish in group.
TS = Daily total number of fish still surviving.

$$\text{Total percentage survival} = \frac{TS}{EP} \times 100$$

Where TS = Daily total number of fish surviving after 14 days.
EP = The experimental population at the start of the experiment.

In order to establish the effectiveness of separate one hour 250 ppm and 500 ppm formalin bath treatments against monogenean and trichodinid gill and skin infestations, fifteen *C. gariepinus* juveniles were randomly selected from

a hatchery pond with a confirmed high prevalence of parasites. The fifteen *C. gariepinus* juveniles were randomly assigned to three groups, namely:

Group 3 (n=5) : Untreated Control Group.

Group 2 (n=5) : Treated for one hour in a 500 ppm formalin bath.

Group 1 (n=5) : Treated for one hour in a 250 ppm formalin bath.

Except during treatment when they were transferred to smaller containers containing the formalin without aeration, fish were kept in 50 liter aerated containers. Parasite counts were conducted on all three groups ~72 hours after treatment. Parasites were collected by skin scrapings limited to one side of a fish and by removal of the gills and preparing a gill squash. Parasites in the skin scrapings and gill squashes were subsequently counted under a dissection microscope. If no parasites were found on the skin of a fish, a skin scraping of the other side was made and examined to prevent false negative results. During the parasite assessment *I. multifiliis* were also found on the fish and it was decided to include these counts in the results and efficacy analysis. Any mortalities of fish after treatment were recorded daily. The following experimental schedule was followed:

Day 0 : Treat Groups 1 and 2.

Day +3 : Count parasites on fish in Groups 1 to 3.

The effectiveness of the treatments were calculated using the following formula:

$$\text{Efficacy} = \frac{C-T}{C} \times 100$$

Where C = Average parasite count from control group.

T = Average parasite count from treatment group.

5.3 RESULTS

Two weeks after the initiation of the experiment, only 7.86% of the fish infested with *Ichthyophthirius multifiliis* in the control group were still alive. The percentage survival in the two treatment groups were, however, much higher than that of the control group and 24.5% of the fish in Group 2 and 44.0% of the fish in Group 3 were still alive (Table 1 and Figure 1).

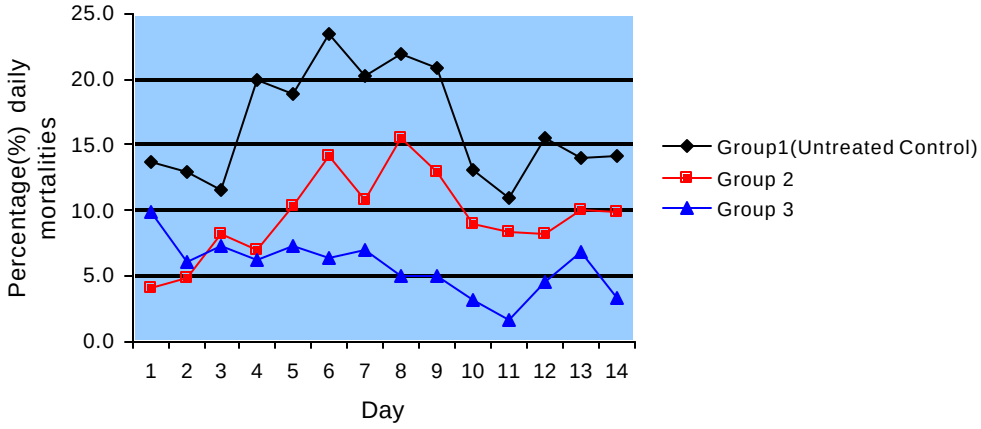

Figure 1. **The daily percentage mortalities of juvenile *Clarias gariepinus* suffering from *Ichthyophthirius multifiliis* infestation after two treatments seven days apart with 16 ppm formalin flush exposure for 24 hours (Group 2) and a 111 ppm formalin bath exposure for 1 hour (Group 3).**

Table 1. **Daily percentage mortalities of juvenile *Clarias gariepinus* suffering from *Ichthyophthirius multifiliis* infestation after two treatments seven days apart with 16 ppm formalin flush exposure for 24 hours (Group 2) and a 111 ppm formalin bath exposure for 1 hour (Group 3).**

	*DAILY PERCENTAGE MORTALITIES (%)		
Day	Group1 (Untreated Control)	Group 2 (formalin flush)	Group 3 (formalin bath)
1	13.6	4.2	9.8
2	12.9	4.9	6.1
3	11.6	8.2	7.3
4	20.0	7.0	6.2
5	18.9	10.3	7.2
6	23.5	14.1	6.3
7	20.2	10.8	7.0
8	21.9	15.6	5.0
9	20.8	12.9	5.0

10	13.1	8.9	3.1
11	11.0	8.4	1.6
12	15.5	8.1	4.6
13	14.0	9.9	6.8
14	14.2	9.8	3.3
****Total percentage survival**	**7.86**	**24.50**	**44.00**

* Mortalities were calculated daily as a percentage of the daily surviving fish in each group.

** Total percentage survival was calculated by calculating the fish surviving as a percentage of the fish population at the beginning of the study period.

The two formalin bath treatments at a dosage of 111 ppm for one hour (Group 3) were therefore more effective in reducing mortalities due to *Ichthyophthirius multifiliis* infestation than two 24 hour formalin flush treatments at a dosage level of 16 ppm (Group 2).

The one hour 250 ppm formalin bath was 100% effective in eradicating gill infestations of *Ichthyophthirius multifiliis* and trichodinids but was only 96.88% effective against monogeneans (Tables 2 and 4).

The one hour 500 ppm formalin bath was 100% effective in eradicating gill infestations of monogeneans and trichodinids but was only 88.89% effective against *Ichthyophthirius multifiliis* (Tables 2 and 4).

Table 2. **The total number of monogeneans, *Ichthyophthirius multifiliis* and trichodinids on the gills of juvenile *Clarias gariepinus* exposed to a one hour 250 ppm (Group 1) and 500 ppm (Group 2) formalin bath.**

GILLS			
Parasites	**Group 1 (n=5)**	**Group 2 (n=5)**	**Group 3 (Untreated control) (n=5)**
Monogeneans	2	0	64
Ichthyophthirius multifiliis	0	1	9
Trichodinids	0	0	20

Table 3. **The total number of *Ichthyophthirius multifiliis* and trichodinids on the skin of juvenile *Clarias gariepinus* exposed to a one hour 250 ppm (Group 1) and 500 ppm (Group 2) formalin bath.**

SKIN			
Parasites	**Group 1 (n=5)**	**Group 2 (n=5)**	**Group 3 (Untreated control) (n=5)**

Ichthyophthirius multifiliis	0	0	8
Trichodinids	0	0	1

Both the one hour 250 ppm and 500 ppm bath was 100% effective in eradicating *Ichthyophthirius multifiliis* and trichodinid skin infestations (Tables 3 and 5). The percentage survival of juvenile *Clarias gariepinus* with an average length of 9.03 cm ranging between 7 cm and 12 cm was 100%, 72 hours after treatment.

Table 4. **The percentage efficacy against monogeneans, *Ichthyophthirius multifiliis* and trichodinids on the gills of juvenile *Clarias gariepinus* after a one hour 250 ppm (Group 1) and 500 ppm (Group 2) formalin bath.**

PERCENTAGE EFFICACY		
Parasites	**Group 1**	**Group 2**
Monogeneans	96.88%	100%
Ichthyophthirius multifiliis	100%	88.89%
Trichodinids	100%	100%

Table 5. **The percentage efficacy against *Ichthyophthirius multifiliis* and trichodinid parasites on the skin of juvenile *Clarias gariepinus* after a one hour 250 ppm (Group 1) and 500 ppm (Group 2) formalin bath.**

PERCENTAGE EFFICACY		
Parasites	**Group 1**	**Group 2**
Ichthyophthirius multifiliis	100%	100%
Trichodinids	100%	100%

5.4 DISCUSSION

Ectoparasiticides

Formalin is probably the most commonly therapeutic water medication used by catfish farmers in South Africa for the control of ectoparasites. Juvenile *C. gariepinus* of an average length of 9.3 cm tolerated one hour bath treatments with this compound at a dosage of 500 ppm. According to Theron, Prinsloo

and Schoonbee (1991), mortalities of *Clarias gariepinus* juveniles treated with one hour formalin baths at a dose rate of 200 ppm varied between four day, 12 day and 20 day old fish. The mortalities they recorded were 1.7% in four day old fish, 1.0% in 12 day old fish and 16.3% in 20 day old fish 72 hours after treatment. The higher mortalities of older fish may to some extent have been due to the development of the subbranchial membrane and the epibranchial organ (Theron *et al*., 1991). It therefore seems that in the present study there was a higher tolerance in older fish to formalin treatments since no mortalities were found in fish with an average length of 9.3 cm after one hour 250 ppm and 500 ppm formalin treatments.

Table 6. A summary of commonly used ectoparasiticide, method of administration, dosages used and known pathogen effectiveness in fish culture (Noga, 2000; Treves-Brown, 2000).

Ectoparasiticides	Compound	Administration	Dosage	Known effectiveness against
Trichlorfon	Organo-phosphorus	Bath	6.25 ppm for 60 min 12.5 - 50 ppm for 30 min 100 ppm for 10 min	Juvenile *Lernaea* spp. and *Argulus* spp.
Dichlorvos	Organo-phosphorus	Bath	1 ppm for 30 to 60 min	Juvenile *Lernaea* spp. and *Argulus* spp.
Azamethiphos	Organo-phosphorus	Bath	0.1 ppm for 60 min	Juvenile *Lernaea* spp. and *Argulus* spp.
Ivermectin		Oral (In feed)	Feed 0.05 mg/kg	Possibly *Argulus* spp.
Cypermethrin (Excis)	Pyrethroid	Bath	0.5 ml/m3 water for 1 hour	Possibly *Argulus* spp.
Formalin	37% to 40% Formaldehyde	Prolonged immersion Bath	15 to 25 ppm for 24 hours 200 ppm for 1 hour in fish < 20 days old 250 ppm for 1 hour for juvenile fish	*Chilodonella* spp., *Epistylis* spp., *Ichthyobodo (Costia) necator*, *Ichthyophthirius multifiliis*, *Trichodina* spp., *Dactylogyrus* spp., *Gyrodactylus* spp.
Mebendazole	Benzimidazoles	Prolonged immersion Bath	25 mg/l for 12 hours 100 mg/l for 10 minutes	Monogenean flukes
Parbendazole	Benzimidazoles	Prolonged immersion	25 mg/l for 12 hours	Monogenean flukes
Fenbendazole	Benzimidazoles	Prolonged immersion	25 mg/l for 12 hours	Monogenean flukes
Mebendazole-Trichlorfon	Benzimidazoles-Organo-phosphorus	Prolonged immersion	0.4 ppm Mebendazole 1.8 ppm Trichlorfon for 24 hours	Monogenean flukes

Formalin- Malachite green (Leteux-Meyer Mixture)	37% to 40% Formaldehyde - Diarylmethane dye	Prolonged immersion	25 ppm formalin + 0.1 mg/l malachite green every other day for three days	Synergistic for *Ichthyophthirius multifiliis*

It must be stressed that the numbers of fish used in the present study were too low to regard the results as significant. The results, however, give an indication of the possible tolerance levels of the fish to formalin treatments. The safety of these dose rates should therefore be tested on larger numbers of fish before applying them to fish in large aquaculture systems. Although formalin is the most commonly used ectoparasiticide, there are a number of other compounds that could also be used. These include organo-phosphorous, pyrethroid and benzimidazole compounds (Table 6). Organo-phosphorous compounds such as Trichlorfon, Dichlorvos and Azamethiphos are effective against fish louse species and are commonly used in bath treatments against these parasites (Noga, 2000; Treves-Brown, 2000). Another compound also effective against fish louse species and which could be used in bath treatments is Cypermethrin. It must be stressed that these treatments and the dose rates summarized in Table 6 are general treatments used in fish aquaculture and the safety of some of them with regard to *C. gariepinus* have not been experimentally evaluated.

Anti-microbials

The safety of malachite green, which is considered as one of the most effective treatments against water mould infections, has also been investigated by Theron *et al.* (1991). Mortalities recorded by them after different malachite green bath treatments are summarized in Table 7.

Table 7. The mortalities of juvenile *Clarias gariepinus* as recorded by Theron, Prinsloo and Schoonbee (1991), after different malachite green bath treatments.

Fish age	Treatment Type and Concentration	Duration of Treatment in seconds	Cumulative Mean % Mortalities (± S.D.) after 72h
4-day old	Malachite green 100 mg/l	10 s	0.7 ± 0.47
		30 s	99.7 ± 0.47
		90 s	100.0 ± 0.00

12-day old	Malachite green 100 mg/l	10 s	0.0 ± 0.00
		30 s	74.7 ± 25.77
		90 s	100.0 ± 0.00
20-day old	Malachite green 100 mg/l	10 s	17.0 ± 10.23
		30 s	47.3 ± 9.39
		90 s	96.7 ± 3.30

The tolerance of juvenile *C. gariepinus* radically decreases with an increase in exposure time to malachite green (Table 7).

Bath treatments with malachite green should therefore never exceed 10 seconds at a dose rate of 100 ppm and must be applied at an age younger than 20 days or at an age at which the subbranchial organ has adequately developed in juvenile fish. Some evidence exists that methylene blue also reduces the incidence of water mould infections and bacterial infections of eggs of freshwater fish (Noga, 2000). The latter treatment was used by the farmers in the Vaalharts hatchery as a prophylactic treatment against water mould infections.

Although formalin is routinely used as an ectoparasiticide it is also a standard general disinfectant used in hatcheries for the prevention of infections of eggs with fungi, the most important of which belong to the genus *Saprolegnia* (Treves-Brown, 2000). Formalin and malachite green can also be used in a combination known as the Leteux-Meyer mixture. Commonly used antimicrobials are summarized in Table 8.

Table 8. A summary of commonly used antimicrobials, methods of administration, dosages used and known effectiveness against specific pathogens (Noga, 2000; Treves-Brown, 2000).

Antimicrobials	**Compound**	**Administration**	**Dosage**	**Known effectiveness against**
Formalin	37% to 40% Formaldehyde	Prolonged immersion Bath	15 to 25 ppm for 24 hours 200 ppm for 1 hour in fish < 20 days old 250 ppm for 1 hour for juvenile fish	*Saprolegnia* spp.
Malachite green	Diarylmethane dye	Bath	Eggs: 1500 µg/l for 5 seconds Larvae: 60 mg/l 10 seconds	*Saprolegnia* spp.

Methylene blue	--	Prolonged immersion	3 mg/l	*Saprolegnia* spp.
Formalin- Malachite green (Leteux-Meyer Mixture)	37% to 40% Formaldehyde - Diarylmethane dye	Prolonged immersion	25 ppm formalin + 0.1 mg/l malachite green	*Saprolegnia* spp.

Antibiotics

Antibacterial drugs are the most extensively used medicinal product in fish culture. These products are divided into several groups, but despite their chemical diversity they are used for one common purpose – either to kill, or to inhibit the multiplication of bacteria (Treves-Brown, 2000). In selecting an antibacterial drug the farmer must ensure that the drug will be efficacious against the bacterial pathogen. Although fish can be treated in immersion baths containing antibiotic, the antibacterial agents are not absorbed from the water by the fish and can therefore only be used for the treatment of topical bacterial infections.

Table 9. A summary of commonly used antibiotics, methods of administration, dosages used and known pathogen effectiveness in fish culture (Noga, 2000; Treves-Brown, 2000).

Antibiotics	Compound	Administration	Dosage	Known effectiveness against
Amoxicillin trihydrate	Penicillins	Oral	Feed 40 to 80 mg/kg b.w. per day for 10 days	*Edwardsiella* spp. and *Aeromonas* spp.
Ampicillin sodium	Penicillins	Oral	Feed 50 to 80 mg/kg b.w. per day for 10 days	*Edwardsiella* spp. and *Aeromonas* spp.
Enrofloxacin	Fluorinated quinole	Bath Oral	2 mg/l for 5 days Feed 10 mg/kg b.w. per day for 10 days	*Aeromonas salmonicida*
Oxolinic acid	Quinole	Bath Prolonged immersion Oral	25 mg/l for 15 minutes twice daily for 3 days 1 mg/l for 24 hours Feed 10 mg/kg b.w. per day for 10 days	gram negative bacteria
Oxytetracycline hydrochloride	Tetracycline	Bath Prolonged immersion Oral	10 to 50 mg/l for 1 hour 10 to 100 mg/l for 1 to 3 days Feed 55 to 83 mg/kg b.w. for 10 days	Columnaris disease and *Aeromonas salmonicida*
Sulfadimethoxine-Ormetoprim	Potentiated Sulfonamide	Oral	50 mg/kg B.W. per day for 5 days	*Aeromonas* sp. *Edwardsiella* sp.

Systemic bacterial infections must therefore be treated through in-feed oral administration of an antibacterial compound. As with any other food animal, the withdrawal period of fish treated with an antibiotic must be established from local authorities before they are marketed. The commonly used antibiotics are summarized in Table 9.

Anthelmintics

Cestodes and nematodes rarely pose a problem in fish aquaculture. Of the fish slaughtered to date (n = 300) in the study area, no cestodes or nematodes were found. If fish are, however, infected with cestodes or nematodes, they can successfully be treated by in-feed oral medication with either Fenbendazole (for non encysted nematodes), Piperazine Sulphate (for non encysted nematodes) or Praziquantel (for cestodes). Commonly used anthelmintics are summarized in Table 10.

Table 10. A summary of commonly used anthelmintics, methods of administration, dosages used and known pathogen effectiveness in fish culture (Noga, 2000; Treves-Brown, 2000).

Anthelmintics	Compound	Administration	Dosage	Known effectiveness against
Fenbendazole	Benzimidazoles	Prolonged immersion Oral	2 mg/l once a week for 3 weeks 25 mg/kg b.w. once a day for 3 days	Nonencysted nematodes
Piperazine Sulfate (Piperazine 34%)	Phenothiazine	Oral	10 mg/kg b.w. for 3 days	Nonencysted nematodes
Praziquantel	Praziquantel	Bath Oral	2 mg/l for 1 to 3 hours 50 mg/kg b.w. for 1 day	Cestodes

Before any medication can be administered to fish either by medication of the water or by in-feed medication, the dosage level that is safe for the specific target species of fish must be known. There is not much known about the safety of many medicinal compounds commonly used in fish culture for *Clarias gariepinus* and therefore the safety of these compounds must be established by catfish farmers before any attempt is made to use them.

PROCESSING AND MARKETING

6.1 INTRODUCTION

Finding a market for fish that he has produced is probably the most important task of any prospective farmer. African clariids are considered a high value species and are of great interest to farmers (FAO, 2004). During the year 2000 South Africa produced 65 metric tons of catfish (*Clarias gariepinus*) with a production value of R667 000 (Brink, 2001).

Unfortunately there is no formal wholesale market for *C. gariepinus* in South Africa, so it is up to the producer to develop and establish a market for his fish. There are, however, various methods of processing and marketing fish. Some of these processed forms are:

- Whole – this is the fish in its natural form,
- Drawn – involves the removal of the viscera but leaving the head and skin on,
- Dressed – the viscera and skin as well as the head and fins are removed,
- Steaks – steaks are obtained by cutting cross-sections 20 to 25 mm thick from dressed fish,
- Fillets – this cut contains no bones and is produced by cutting a dorsal side section away from the backbone of a fish of which the skin has been removed, and
- Other processed forms – hot-smoked, cold-smoked, kebabs, fish sticks and cakes, crumbed or battered and sausages (Smith and de Beer, 1988).

The geographic locality of the operation, and whether catfish in a particular area is a “known” entity, will largely determine the way in which it is marketed. This marketing strategy will in turn, influence the processing of the fish.

According to Smith and de Beer (1988) the essence of a successful marketing drive is based upon producing the “right” product at the “right” market price. *Clarias gariepinus* should certainly be regarded worldwide as the “right” product mainly because of:

- Excellent fillets with no floating bone structure,
- Excellent dressed-out percentages,
- Firm, mild flavored flesh that can even be used for kebabs,
- Excellent nutritional value,
- Excellent hot and cold smoking qualities,
- Distinctive pink flesh that could be introduced into sashimi markets, and
- Tough skin that tans excellently.

Overall *C. gariepinus* is a versatile quality product that if processed correctly will meet the needs of any market. Since marketing of the fish produced in the Vaalharts Irrigation Scheme was in progress while writing this chapter, only a few aspects of the product and marketing will be discussed.

The main objective of this chapter is to give a broad overview of the processing and marketing of *C. gariepinus* in South Africa. Together with some of the problems associated with marketing identified in the Vaalharts area, this chapter should provide any prospective *C. gariepinus* farmer with a sound foundation on which to develop his own specific processing and marketing plan.

6.2 MATERIAL AND METHODS

To calculate the average dress-out weight of *C. gariepinus* in it’s various processed forms, a total of 300 fish from the irrigation dam were netted. The fish netted were weighed and the average weights calculated. After weighing the fish, processing was started by trained workers. The processing procedure followed a logical sequence from the least processed product to the most processed product. The processing sequence therefore was as follows:

- Removal of the viscera,
- Removal of the head and fins,
- Removal of fillets,
- Removal of skin from fillets, and
- Processing the fillets by smoking.

Between each of the processing steps the processed forms of the fish were weighed and the average weight calculated. The processed forms weighed were therefore:

- Whole – fish in natural form (Figure 1),
- Drawn – viscera removed (Figure 2),
- Dressed – head and fins removed (Figure 3),
- Fillets with skin – boneless side section of fish (Figure 4),
- Skinless fillets – skin removed from fillets (Figure 5), and
- Smoked fillets – hot smoked fillets (Figure 6).

The average weights calculated of each processed form were consequently used to calculate the dress-out percentage of each processed form.

Figure 1. A photograph of a whole catfish (*Clarias gariepinus*) in it's natural form before processing.

Figure 2. **A photograph of a drawn catfish (*Clarias gariepinus*) with its viscera removed.**

Figure 3. **A photograph of a dressed catfish (*Clarias gariepinus*) with the head and fins removed.**

Figure 4. **A photograph of a filleted catfish (*Clarias gariepinus*) with the skin still attached to the fillets.**

Figure 5. **A photograph of a filleted catfish (*Clarias gariepinus*) with skinless fillets.**

Figure 6. **A photograph of smoked catfish (*Clarias gariepinus*) fillets.**

6.3 RESULTS

The average weight of the processed forms of *C. gariepinus* decreased as processing to more sophisticated products increased. The average weight of the viscera was 34 g, eight percent of the total weight of fish with an average weight of 425 g. The head and fins weighed 102 g, which contributed 24% to the total live weight of the fish, the greatest proportion of all the waste products. The skinless fillets which were the most processed uncooked form yielded a 40% dressing percentage and when smoked, only 31% (Table 1).

Table 1. **The average dress-out percentage and weight of seven different processed forms of *Clarias gariepinus* after processing.**

Processed product	Average weight (g)	Breakdown percentage (%)
Live weight	425	100
Drawn	391	92
Dressed	289	68
Steaks	289	68
Fillets with skin	199	47
Skinless fillets	170	40
Smoked fillets	131	31

6.4 DISCUSSION

In order to successfully market *C. gariepinus* in South Africa the following are necessary:

- A consistent supply of fish which meet specific quality standards,
- Accessibility to processing facilities and processing know-how, and
- Effective distribution channels to deliver the products on a reliable basis.

Currently not one of these key aspects exists in South Africa for *C. gariepinus.* If a catfish industry is to be established in the Vaalharts Irrigation Scheme, the development of not only the production system is very important, but also the processing and marketing of *C. gariepinus.*

Both processing and marketing, if done on a large scale, are unfortunately specialized fields that really need to be managed by people with the right know-how. In the Vaalharts Irrigation Scheme there could be two approaches to the processing and marketing of fish. Firstly farmers could practice smallscale on-farm processing of their own fish and market the fish direct to the customers. In direct selling the farmer will capture all or a very large portion of the marketing margin. But direct selling is not necessarily easy. It is very difficult for an individual producer to establish business relationships with wholesalers, grocers or restaurants. Moreover, these direct sales outlets may have very strict requirements for their suppliers.

Another issue to consider is that direct sales to local grocery stores and restaurants will probably require on-site processing unless the restaurant personnel clean the fish. The ability to process fish on-site will probably require the farmer to have a functioning Hazard Analysis and Critical Control Points (HACCP) plan in place. Also in direct selling, the farmer assumes a great deal more liability for product safety or quality than in selling to a

processor. The major problem with direct sales to consumers is that this is typically a very low volume market outlet.

The second approach could be the establishment of a single processing facility in the Vaalharts Irrigation Scheme, servicing all the producers in the area and supplying fish to a single marketing company. The advantage of this would be:

- The prevention of rivalry between producers.
- The combined fish production by farmers will ensure a consistent supply of fish.
- The larger volumes of fish produced would also justify establishing a marketing company.
- The larger volumes of fish produced to be processed will justify the building of a HACCP approved processing plant.
- The larger volumes of fish produced will make the export of fish to existing markets a possibility.
- The production of fish in the area can be synchronized to ensure a consistent supply of fish all year round.

In the Vaalharts Irrigation Scheme the problems associated with small scale on farm processing and direct marketing are currently evident. The estimated 7 000 kg of stock in the irrigation dam does not justify the purchase of any specialized processing equipment. Furthermore it is up to the farmer to market the fish and create outlets, especially in the resource-poor communities, which are the largest market in this area. All this extrapolates into more capital investment by the farmer. Some of the specific problems with marketing encountered in the Vaalharts area are:

- A stigma associated with catfish in South Africa as a poor quality product not fit for consumption causes consumer resistance in up market urban areas.

- The novelty of catfish with retailers, restaurants and wholesalers relates into product resistance.
- Competition with cheaper inferior sea fishery products in the resource-poor communities.
- The lack of cooling facilities at outlets in the resource-poor communities where the product is readily accepted.

A large capital investment into marketing will be required to overcome these problems and to introduce *C. gariepinus* to the various markets as a quality product. Attention must also be paid to the development of new products such as for example catfish kebabs (Figure 7).

Figure 7. A photograph of an example of new catfish (*Clarias gariepinus*) products like kebabs.

Since little capital investment is needed towards grow out dams in the Vaalharts Irrigations Scheme, a high initial investment into marketing and processing facilities would still be economically feasible. The excellent feed conversion rates, high production capabilities, excellent dress-out percentages and the quality of the product will make *C. gariepinus* farming in

the Vaalharts Irrigation Scheme a very lucrative business if a market can be developed.

If the dress-out percentage of *C. gariepinus* is compared to that of other production fish species the excellent dress-out percentage of this species is evident (Table 2).

Table 2. The dress-out percentages of four different production fish species.

Fish specie	Product	Dress-out percentage
Sharptooth catfish *(Clarias gariepinus)*	Dressed	68%
	Fillets	40%
[1]*Tilapia* sp.	Dressed	51-53%
	Fillets	32-35%
[2]Channel catfish *(Ictalurus punctatus)*	Dressed	60%
	Fillets	35%
[3]Bighead carp *(Hypophthalmichthys nobilis)*	Dressed	66%
	Fillets	31%

[1] (Popma and Masser, 1999)

[2] (Silva and Dean, 2001)

[3] (Stone, Engle, Heikes and Freeman, 2000)

Although *C. gariepinus* is an excellent product, it could be ruined through wrong processing practices. If spoiled products or low quality products are allowed to reach consumers it could result in a collapse of an existing market for *C. gariepinus*. It is therefore of the utmost importance that the highest quality standards must be adhered to while processing *C. gariepinus*.

Basic Procedures for Quality Control

The following is an overview for basic quality control procedures for catfish (*Ictalurus punctatus*) processing plants according to McGilberry, Culver, Brooks, Hood, Dean and LaBruyere (1989):

- Fish should be checked for pesticide, herbicide and heavy metal residues, as well as diseases and off-flavor.

- Holding tanks that are used to store fish prior to processing should be kept free of algal growth, and proper levels of dissolved oxygen should be maintained. High quality water should be used.
- Proper cleaning procedures, including heading, eviscerating and skinning, should be conducted at all times. Periodic checks should be made at every location during processing.
- Proper offal removal procedures should be carefully monitored and maintained.
- A proper chilling procedure, using the latest chilling techniques, should be used to reduce and then maintain the temperature of the catfish at 3°C throughout processing.
- All surfaces in contact with the fish should be sanitary and not have contact with the floor.
- Fish dropped on the floor should be handled in a proper manner using correct washing methods.
- The temperature of fish products that are to be frozen should be reduced to -18°C as rapidly as possible and they should promptly be stored in a freezer at -23°C to -29°C.
- All work-in-process fresh inventory should be promptly iced and stored at approximately 1°C.
- Every effort should be made to keep bacterial counts low. Routine monitoring of product and equipment is encouraged.
- Frozen product should be properly stored in a freezer.
- Freezer stock should be rotated regularly.
- Proper clean-up in a plant is essential.
- Product should be checked throughout the processing operation with regard to weight, size, visual appearance, proper temperature and correct packaging.
- Value added products should routinely be checked on-line to ensure proper percentage of marinade, glaze, etc.
- Product recall procedures, including proper coding of a product, should be used.

All these facets should be covered in greater detail by a Quality Assurance program.

Clarias gariepinus production has the potential of developing in a large industry in the Vaalharts Irrigation Scheme. Although consumer resistance will be a problem if the fish are sold locally, extensive export markets exist in Europe and Asian countries. To enter these export markets large volumes of fish must be produced on a monthly basis. The Vaalharts Irrigation Scheme has the potential to easily produce the volumes of fish required to enter these markets. It will, however, require a very large capital investment to realize the export of fish. Although the initial capital investment will be large, the export of fish should still be profitable, since no investment into the production infrastructure will have to be made.

The benefits to the community of *C. gariepinus* production in the Vaalharts Irrigation Scheme will be immense. A whole new industry could be established within an existing infrastructure, thus adding value to the current farming activities. In addition to this, a number of new job opportunities will be created through the production and processing of *C. gariepinus* in this area.

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ABSTRACT

A practical investigation into factors influencing the success of catfish (*Clarias gariepinus*) farming in the Vaalharts Irrigation Scheme was undertaken. These factors were production, nutrition, disease, disease treatment, processing and marketing. Flow-through tarpaulin ponds in the Vaalharts Irrigation Scheme were used very successfully for the propagation and rearing of *Clarias gariepinus*. The growth rate of *Clarias gariepinus* fingerlings stocked in an irrigation dam and a tarpaulin flow-through pond was determined and compared. The highest specific growth rate (1.61% bw/day) of fish in the irrigation dam coincided with the highest average monthly water temperature (26°C) recorded during the month of January 2005. The specific growth rate of fish in the flow-through ponds was lower (<1.27% bw/day) than that of fish in the irrigation dam. Fingerlings stocked at an average size of 8.9 g in the irrigation dam reached a size of 450 g within 216 days. The nutritional value and feed conversion rates (FCR) of two feed formulations were determined and compared. The percentage protein of these two feeds was 22.07% and 33.50%, respectively. Higher percentage feed protein levels coincided with better feed conversion rates. Except for an outbreak of white spot disease (*Ichthyophthirius multifiliis*) in one hatchery pond, no significant mortalities of fish were recorded as a result of parasite infestations. Parasitic infestations were successfully treated in the Vaalharts hatchery using prophylactic formalin bath treatments. Fish processed yielded a fillet dress-out percentage of 40%. Consumer resistance for catfish products were found in urban markets. In the semi-urban informal settlements, however, catfish were readily accepted.

Key words: *Clarias gariepinus*, Vaalharts Irrigation Scheme, irrigation dam, tarpaulin flow-through pond, growth rate, specific growth rate, feed conversion rate.

OPSOMMING

'n Praktiese ondersoek na die faktore wat die suksesvolle produksie van babers (*Clarias gariepinus*) in die Vaalhartsbesproeiingskema kan beïnvloed, is onderneem. Die faktore wat ondersoek is het produksie, voeding, siektes, behandeling van siektes, verwerking en bemarking ingesluit. Deurvloeibokseildamme in die Vaalhartsbesproeiingskema is met groot sukses vir die aanteel en grootmaak van *C. gariepinus* gebruik. Die groeitempo van *C. gariepinus* in 'n deurvloeibokseildam en 'n besproeiingsdam is bepaal en vergelyk. Die hoogste spesifieke groeitempo (1.61% liggaamsgewig/dag) van babers in die besproeiingsdam het met die hoogste gemiddelde maandelikse water temperature (26°C) wat gedurende Januarie 2005 aangeteken is ooreengekom. Die groeitempo van babers in die bokseildeurvloeidamme was laer (<1.27% liggaamsgewig/dag) vergeleke met die besproeiingsdam. Vingerlinge in die besproeiingsdam, met 'n gemiddelde gewig van 8.9 g, het 'n gemiddelde gewig van 450 g in 216 dae bereik. Die voedingswaarde en voer omsettingstempo van twee voerformulerings is bepaal en vergelyk. Die proteïenwaarde van die twee voere was 22.07% en 33.50%, onderskeidelik. Hoër proteïenwaardes het voorts met beter voeromsettingswaardes ooreengestem. Behalwe vir 'n uitbraak van witkolsiekte (*Ichthyophthirius multifiliis*) in een van die uitbroeidamme, is geen betekenisvolle vrektes as gevolg van parasietinfestasies aangeteken nie. Parasitiese infestasies in die Vaalhartsbroeiery is suksesvol voorkomend behandel met formalienbaddens. Verwerkte vis het 'n 40% mootjieopbrengs gelewer. Verbruikerweerstand teen die gebruik van baberprodukte is in stedelike gebiede gevind. Hierteenoor is gevind dat baberprodukte geredelik deur persone in informele nedersettings aanvaar word.

Sleutelwoorde: *Clarias gariepinus*, Vaalhartsbesproeiingskema, besproeiingsdam, bokseildeurvloeidam, groeitempo, spesifieke groeitempo, voeromsettingswaarde.

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