The culture of sharptooth catfish, *Clarias gariepinus* in southern Africa

T Hecht, W Uys and P J Britz (editors)

A report of the National Programme for Aquaculture Research

SOUTH AFRICAN NATIONAL SCIENTIFIC PROGRAMMES REPORT NO

153

1988

Issued by

Foundation for Research Development
CSIR
P O Box 395
PRETORIA
0001

from whom copies of reports in this series are available on request.

Printed in the Republic of South Africa in 1988

ISBN 0 7988 4498 1

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GAcsir 24H5062*8810

PREFACE

The potential for sharptooth catfish, *Clarias gariepinus* culture throughout Africa has been recognized for the last four decades. The technological advances towards this aim have been rapid in comparison to the development of the culture techniques of other species. To a great extent this can be ascribed to the dedication of those scientists in Africa and abroad who have believed in the potential of this species as a candidate for aquaculture. A significant contributing factor has also been our relatively good understanding of the biology and ecology of the species. To a large extent this reflects the importance of fundamental research as a foundation for applied research. Research on the culture of catfish southern Africa started in the early 1970's. Since then the work has followed a natural progression: from artificial spawning, larval rearing, larval and juvenile nutrition, pond production, disease control to processing and marketing. While this work was being undertaken a parallel research effort was taking place in the Netherlands. This juxtaposition has been a contributing factor to the rapid development of the technology for catfish culture throughout Africa. The technology has now developed to a point where there are no major scientific constraints to impede the development of the industry.

Presently catfish are cultured on a private enterprise basis in southern Africa and the Netherlands as well as on a subsistence level elsewhere in Africa. In southern Africa commercial catfish farming is now entering an exponential growth phase. The decision to hold a workshop was taken as a means to guide this rapid development of the industry in an orderly and rational manner. The two major objectives were, firstly, to synthesize our knowledge of catfish culture for the benefit of the existing, as well as for the prospective, catfish farmer and secondly to identify future research needs to further expedite the growth of the industry.

A total of 16 delegates actively participated in the workshop. These included scientists and producers. A list of names and addresses are appended at the end of the document. The workshop was held on 28 and 29 January 1988 on the catfish farm "Moirah" of Wynand and Marie-Tinka Uys along the Blyde River in the Transvaal lowveld.

The proceedings of this workshop are not intended to serve as a definitive manual for the successful commercial culture of catfish in the sub continent. They should rather be viewed as a set of guiding principles.

Thomas Hecht
Workshop Chairman and Editor

ABSTRACT

The report presents the proceedings of a two-day workshop held on the sharptooth catfish farm "Moirah" of Mr W Uys in the Eastern Transvaal in late January 1988. The overall aim of the workshop was to synthesize the available information on the culture of this important species in order to provide a skeletal guideline for prospective entrepreneurs. In the second instance the workshop also served to identify the research needs for the refinement of husbandry techniques.

Chapter 1 is an overview of the biology and ecology of the species. Particular emphasis is given to the intrinsic value of natural history studies and the benefits of such studies to the intensive culture of the species.

Chapter 2 summarizes the history of sharptooth catfish culture throughout Africa and elsewhere, although particular attention is given to the development of culture techniques on the subcontinent. This chapter also serves as a guide to the literature on clariid culture.

Chapter 3 deals with the important technical issues of site selection and planning as well as pond construction.

Chapter 4 provides a brief overview of artificial propagation of the species and fingerling production. The advantages and disadvantages of various techniques are discussed and recommendations are made how to best achieve success. A design for a catfish hatchery is also provided.

Chapter 5 reviews fundamental aspects of fish nutrition and then proceeds to summarize the dietary requirements of sharptooth catfish larvae and juveniles. The important issue of least cost diet formulation is also covered and practical diets for the intensive culture of catfish are recommended.

Chapter 6 provides practical guidelines for the intensive rearing of larvae and the intensive culture of fish in earthern ponds. Guidelines, in terms of stocking, feeding, water supply, size sorting and harvesting are also provided for nursery and production pond management.

Chapter 7 deals with the processing of freshwater fish and in particular with sharptooth catfish. Throughout the chapter the provision of a top quality product to the market is stressed.

Chapter 8 deals with the complex subject of introducing a new product onto the market. Pertinent guidelines for the management of marketing are provided.

Chapter 9 reviews the bacterial and viral diseases which have been encountered in clariid fishes. No serious viral or bacterial diseases have been found on southern African sharptooth catfish farms. However, it is predicted that coupled with the upswing in the industry and higher stocking densities it is inevitable that diseases will manifest themselves.

Chapter 10 lists the parasites that have been found on sharptooth catfish under natural conditions as well as in culture systems. These include protozoans, fungi, monogenetic trematodes, digenetic trematodes, cestodes, nematodes and crustaceans. The authors also refer to the important interplay between the environment and the fish and the reasons for parasite population explosions.

Chapter 11 summarizes the technique of cryopreservation of sharptooth catfish sperm. The value in terms of genetic selection and controlled breeding programmes is stressed.

Chapter 12 provides an introduction to the financial planning of a sharptooth catfish farm. This issue alone is as important to the ultimate success of a catfish farm as all the other issues combined.

Chapter 13 summarizes the legal implications in the development of a fish farm. Although there are no specific regulations governing catfish farming the information provided is of cardinal importance for the establishment of a commercial sharptooth catfish farm. The value of this chapter lies in the precise manner in which the channels, which a prospective entrepreneur has to follow in order to commence, have been identified.

Chapter 14 highlights several of the issues discussed during the workshop and suggestion are made for specific projects which should be given priority for future research.

ACKNOWLEDGEMENTS

The hard organizational work by Dr Danny Walmsley and Mrs Louise Botten of the Aquaculture Research Programme of the Foundation for Research Development of the CSIR contributed largely to the success of the workshop.

Grateful acknowledgement is made to Wynand and Marie-Tinka Uys who hosted the workshop on their farm "Moirah" in the Hoedspruit district in the Eastern Transvaal.

We would also like to thank Andy Scholtz for his unfailing support in matters technical and for his help in the final preparation of the manuscript and for compiling the parasite treatment table.

We thank all the contributors for the prompt submission of their manuscripts. This certainly eased the task of the editors. We also thank all the other delegates who participated so actively and constructively.

The workshop was financed by the Aquaculture Programme through the Ecosystem Programmes of the Foundation for Research Development of the CSIR.

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CHAPTER 1. SYSTEMATICS AND BIOLOGY OF CLARIID CATFISH

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INTRODUCTION

Catfish constitute a large group of primarily freshwater fish which are widely distributed throughout the world. They reach their greatest diversity in the continents spanning the equator - South America, Africa and Asia - and are especially specious in the largest rivers such as the Amazon and Zaire, in each of which several hundred species are found. Some catfish are armoured with heavy scales but most are scaleless. They vary in size from tiny parasitic species with a total length of less than five millimetres to giant forms such as the eels, vundu and sharptooth catfish which weigh 30 kg in mass. Most catfishes prefer the slow-flowing reaches of rivers and lakes, but there are exceptions such as the mountain catfish in South Africa, *Amphilius uranoscopus*, which lives in fast-flowing rapids. Catfish are typically very adaptable and hardy animals which can survive out of water for considerable periods of time if they remain moist. They are therefore suitable for intensive culture without aeration or high water exchange rates.

Catfish are characterized by the following anatomical features: a single, rayed dorsal fin, which may be short or long; the presence of an adipose fin in some species; strong, sharply pointed spines in the pectoral (and in some species, the dorsal) fin; whiskerlike, sensory barbels around the mouth; a large and broad head and mouth; small eyes. All catfish have swimbladders and a Weberian apparatus (a string of fused vertebrae which connect the inner ear to the swimbladder) and many have sound-producing and electrogenic organs.

Catfish are classified in the order Siluriformes which includes such familiar fishes as the bullheads, squeakers, electric catfish, sea barbel and armoured catfish, as well as less familiar forms such as the doradids, plotosids, pimelodids and callichthyids. There are about 2 000 species of catfish in the world (about eight per cent of the total number of fishes) and about 42 species (of which eight are undescribed) occur in southern Africa (unpublished records of the JLB Smith Institute of Ichthyology). Most southern African catfishes are either too small, too difficult to culture or would encounter too much consumer resistance to be successful aquaculture candidates. Only three southern African species, the sharptooth catfish *Clarias gariepinus*, the vundu *Heterobranchus longifilis* and the butter catfish *Eutropius depressirostris*, are considered to have aquaculture potential (Figure 1.1).

SYSTEMATICS

The proper classification of candidate species for aquaculture is essential as it is necessary to attach valid scientific names to the species which are cultured. It is also necessary to establish the phylogenetic relationships between species so that valid extrapolations can be made among closely related groups.

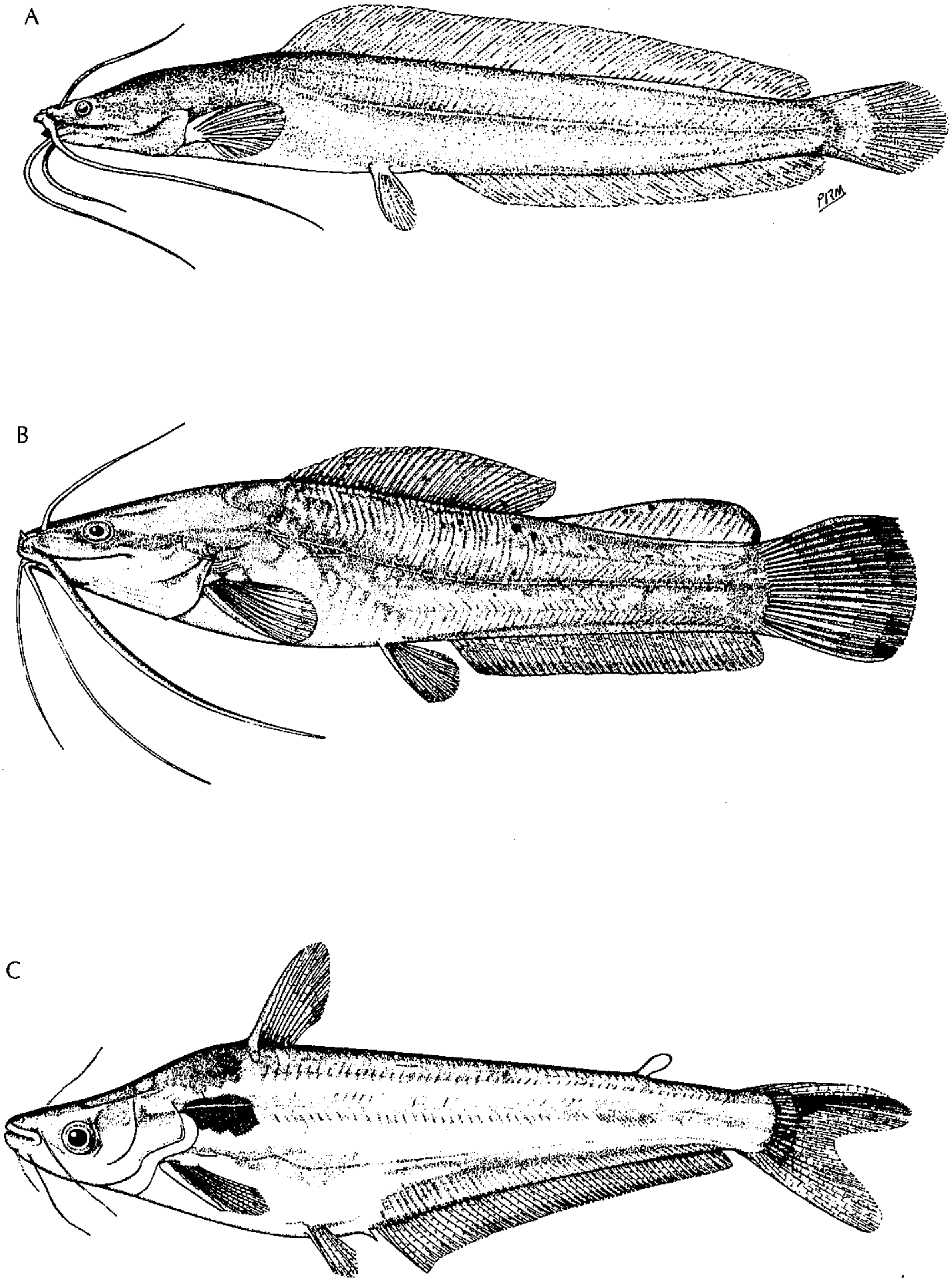

FIGURE 1.1 African sharptooth catfish, *Clarias gariepinus* (A), the vundu, *Heterobranchus longifilis* (B) and the butter catfish, *Eutropius depressirostris* (C).

Regrettably the taxonomy of most southern African catfish groups is still in a state of flux. The butter catfish belongs to the family Schilbeidae, which is characterized by a compressed body and depressed head with a long anal fin, a short rayed dorsal fin with a sharp spine and a small or no adipose fin. There are also sharp spines in the pectoral fins. Schilbeids are typically shoaling, midwater fish, unlike many other catfishes which are non-social, benthic fishes. Three schilbeid catfishes were previously thought to occur in southern Africa: *Eutropius depressirostris*, *E yangambianus* and *Schilbe mystus*. De Vos (1986) synonymized *E depressirostris* with *Schilbe mystus* and placed *E yangambianus* in *Schilbe yangambianus*. P H Skelton (personal communication) has since pointed out that southern African specimens of *E depressirostris* do not belong to the species *Schilbe mystus* and it is likely that our form will be placed in another species of *Shilbe* in the near future. In the meantime we will continue to use *E depressirostris*.

The fish of the family Clariidae which are characterized by a large armoured head, no spine in the dorsal fin which has a long base, the presence or absence of a long adipose fin, a long anal fin and a suprabranchial organ for air breathing. There are eight clariid species in southern Africa, of which only the sharptooth catfish, *Clarias gariepinus* concerns us here. Recent revisions of the systematics of African *Clarias* by Teugels (1986) have resulted in several widespread species being synonymized under the name *Clarias gariepinus*. These include *C capensis* of southern Africa, *C mossambicus* of central Africa and *C lazera* of west and north Africa and Asia Minor.

Teugels (1986) placed *C gariepinus* in the subenus *Clarias (Clarias)* with the west African species *C anguillaris*, *C senegalensis* and others. Another southern African species, *C ngamensis*, is placed in the subgenus *Clarias (Dinotopteroides)*. The vundu *Heterobranchus longifilis* is also a member of the Clariidae.

Since these proceedings are concerned mainly with clariid catfish, the remainder of this account will deal with *Clarias gariepinus*. The hybridization of the sharptooth catfish with the vundu is discussed in Chapter 2.

DISTRIBUTION AND HABITAT PREFERENCES

Clarias gariepinus, as presently recognized, ranges from southern Natal and the Orange River in the south northwards through central, west and north Africa, through the Middle East and into eastern Europe. It is the freshwater fish species with the widest latitudinal range in the world (about 70° latitude).

The sharptooth catfish is eurytopic and inhabits a very wide range of inland waters, including streams, rivers, pans, swamps, underground sinkholes, shallow and deep lakes as well as impoundments. They thrive in shallow turbid lakes, such as Lake Ngami and Hyamithi Pan, as well as in deep clear lakes, such as Sibaya, but are particularly successful in fast-flowing rivers.

Their tolerances of environmental extremes, based on my field observation, are as follows:

- water temperature: eight to 35°C, breeding >18°C
- water temperature range for egg hatching: 17 to 32°C
- 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 using the epibranchial organ, epibranchial epithelium, gill fans and possibly the skin on the dorsum which, when active, drowns if denied access to air.
- desiccation: a strong resistance to desiccation as a result of their air breathing habit. When the gills collapse or are clogged with mud, the catfish secrete mucus to keep the skin moist, or dig holes or crude burrows, but they cannot aestivate in a cocoon like the lungfish (Bruton 1979a)
- pH: wide tolerances
- turbidity: wide tolerances
- sibling densities: wide tolerances

Under culture conditions we should not expect *C gariepinus* to perform optimally at the extreme ends of its range of environmental tolerances. Whenever possible they should be cultured near the mode of their environmental tolerances. These are discussed in greater detail in Chapters 4 and 6.

BREEDING

Clarias gariepinus await suitable environmental conditions for spawning, which usually takes place in summer. Gonadal maturation starts in winter and is associated with increasing water temperatures. Spawning in the wild in South Africa takes place at water temperatures above 18°C, usually above 22°C. The size at first maturity varies greatly (150 to 800 mm TL) and is usually at an age of one to three years. The modal size of breeding fishes likewise varies widely, usually between 500 and 850 mm TL (Bruton 1979b). The sharptooth catfish is a fecund species with modal size females producing 50 000 to 200 000 eggs, but fecundities in excess of 1 000 000 eggs have been reported by Gaigher (1977). According to Hogendoorn (1977), the fecundity of northern populations of *C gariepinus* may be estimated using the formula: total number of eggs = 66,6 X female body mass (g).

Clarias gariepinus releases its eggs in shallow water where they adhere to the leaves and stems of plants. Spawning usually takes place at night in recently inundated marginal areas of the lake or river, typically between 20h00 and 02h30 hours and usually after heavy rain (Bruton 1979b). In Lake Sibaya in Zululand catfish spawning took place most often within two or three days of new moon or the last quarter, ie on relatively dark nights. On one night when spawning occurred at full moon, heavy rain (87,6 mm) had fallen and the sky was overcast. On five occasions, all of which associated with the first or the last moon quarter, the spawning run ended abruptly when the overcast sky cleared and relatively bright conditions prevailed. The selective advantage of spawning on dark nights is obvious - the catfish would be less vulnerable to visually-orientating predators, whereas their own breeding activities would not be affected as they apparently rely mainly on nonvisual cues. The time lapse between heavy rain and the initiation of spawning was 10 to 34 hours in Lake Sibaya and eight to 36 hours in other systems (see review by Bruton 1979b).

There is often a massive aggregation before spawning during which the males fight among themselves for the right to court with the females. In rivers massive migrations of catfish may take place before spawning, sometimes numbering thousands of fishes. The courtship rituals are fairly complex and involve the male fish twisting around the female in a U-shape (Figure 1.2). Fertilization of the eggs takes place externally. The sperm are motile for 80 to 120 seconds, which is a very short period compared with the sperm motility duration of tilapias (10 to 12 minutes, J van Vuuren personal communication).

There is no parental care of the young in the sharptooth catfish (as is found in some other catfish, even some clariids) except by the careful choice of a suitable spawning site. The shallow, recently flooded areas usually chosen for spawning are typically free of predators and rich in food resources. Egg and larval development is rapid. The eggs hatch after 24 to 48 hours, depending on the incubation temperature. Rapidly hatching larvae begin to swim 35 hours after ferilization and feed externally after 80 hours. The larvae change to juveniles (when the fin rays begin to appear) after about seven days. The larvae and juveniles are secretive and seek out dark, confined microhabitats where they feed on small invertebrates in shallow inshore areas.

Techniques for the artificial inducement of spawning in *C gariepinus* have fortunately been perfected as it would be extremely difficult to collect sufficient young catfish from the wild for culture purposes.

FEEDING

Clarias gariepinus is equipped to feed on a variety of food organisms from plankton to fish. In Lake Sibaya juveniles up to 50 mm TL fed mainly on chironomid larvae, shrimps and small planktonic or benthic crustaceans. Larger juveniles (to 100 mm TL) fed on the above prey as well as on dragonfly nymphs, fish fry and small crabs. Adult catfish fed on fish, crabs and snails (Bruton 1979c). Predation is most efficient on relatively slow moving bottom-living organisms but fast prey, such as fish, can be caught using pack hunting tactics. The food recorded from catfish stomachs has also included frogs, snakes, fledgling birds and small mammals as well as algae, macrophytes, seeds and fruits. In some systems the adults feed mainly on zooplankton or chironomids whereas in others they feed mainly on fishes and insects. Studies in different parts of the range of *C gariepinus* have revealed that higher growth rates and a larger maximum size are achieved if the diet has a high protein content.

A detailed study in Lake Sibaya in Zululand revealed the following contributions of different prey categories to the diet (Bruton 1979d):

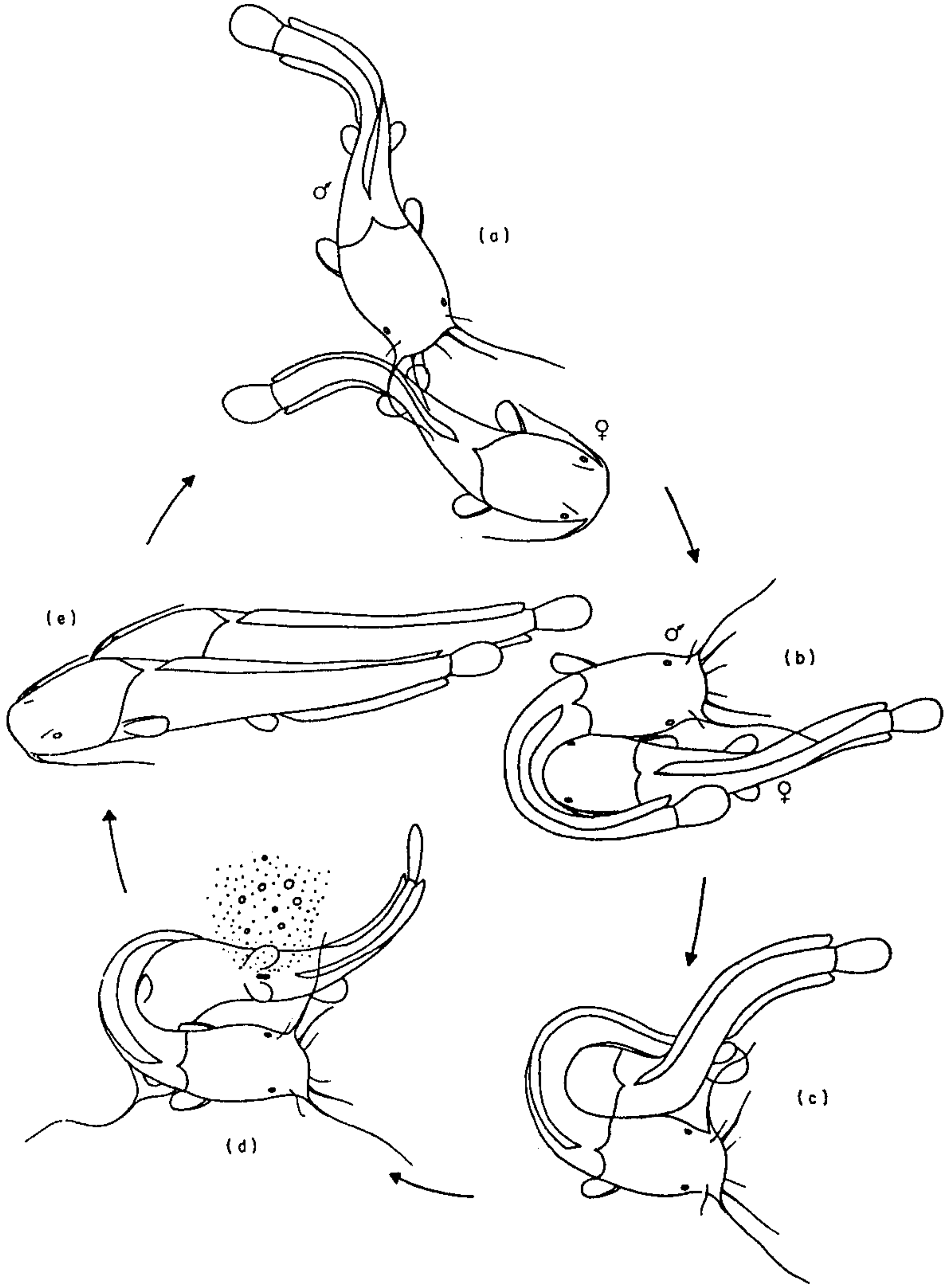

FIGURE 1.2 The courtship ritual of *Clarias gariepinus*.

	% of total prey no	% of total prey dry wt	% of total	Average kJ per prey
Fish	12,5	75,0	76,5	22,8
Crustacea	65,0	18,6	16,5	0,95
Insecta	16,8	4,4	1,7	1,6

Further studies on the contributions of different natural dietary items to energy intake are required.

Under culture conditions, where foraging efficiency for animal prey does not have to be taken into account, the optimal diet should have a high protein content and the correct amino acid balance. *Clarias gariepinus* has a high level of enzyme activity in its digestive tract and relies primarily on enzymatic digestion, rather than acid hydrolysis, to digest its prey. The sharptooth catfish has high levels of amylase, protease and gastric lysozymes, with wide temperature profiles, which facilitate its opportunistic feeding habits and its ability to utilize a wide range of nutrients efficiently. The catfish, is furthermore, physiologically equipped to efficiently utilize infrequent and irregular meals due to the rapid secretory response of the enzymes and the absence of a rhythmic cycle of digestive activity (Uys and Hecht 1987; Uys et al 1987).

GROWTH

Growth rates vary widely in *C gariepinus* but in general, under natural conditions they reach 200 to 300 mm in the first year and have annual increments thereafter of 80 to 100 mm. The maximum size reached in most lakes and small rivers is rarely greater than 20 kg, but very large specimens (sometimes in excess of 40 kg) may be found in large, turbid rivers (Bruton 1976). The growth rates achieved by *C gariepinus* are reviewed by Van der Waal and Schoonbee (1975), Bruton and Allanson (1980), Clay (1979, 1982) and Quick and Bruton (1984).

SENSORY SYSTEMS

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 only appear to be able to detect movement and changes in illumination levels. Sharptooth catfish are primarily active at night and are most efficient at capturing prey at low light levels (Bruton 1979c,d).

PROBLEMS ASSOCIATED WITH THE TRANSLOCATION OF CATFISH

There are some risks associated with the translocation and culture of *C gariepinus* beyond its natural range. This species has all the qualities of an aggressive and successful invader which readily adapts to living in new habitats, ie high fecundity, flexible phenotype, wide habitat preferences and environmental tolerances, ability to feed on a wide range of prey, rapid early development and growth (Bruton 1986). They have colonized the Great Fish River through the Orange-Fish Tunnel

(Laurenson and Hocutt 1985), and have also invaded the Sundays, Black Kei and Tyume Rivers in the eastern Cape as well as the Eerste River in the western Cape (de Moor and Cruton in press).

Catfish in the eastern Cape are threatening the populations of indigenous *Sandelia bainsii* and *Barbus pallidus* as well as the indigenous crab *Potamonautes perlatus*. Studies in east Africa have shown that introduced *C gariepinus* can decimate populations of aquatic invertebrates (Weir 1972). At least 20 species of parasites are carried by *C gariepinus* (Van As and Basson 1984) of which one (*Argulus japonicus*) is an undesirable alien which could be spread to new localities via translocated catfishes. Under intensive culture conditions we can expect parasite and disease problems in the sharptooth catfish to become more severe. If the alien cestode parasite *Bothriocephalus acheilognathi* infests *C gariepinus* it could become far more widespread in South Africa than it is at present and could further threaten indigenous fishes.

Aquaculturalists need to be sensitive to the dangers posed by alien and translocated indigenous aquatic animals, not only because they pose a direct threat to their industry but also because of the negative publicity which will result from outbreaks of diseases etc which arise from fish imported or translocated for aquaculture. It is therefore essential that aquaculturalists should cooperate closely with the conservation authorities and with scientists studying invasive animals, in order to reduce the deleterious effects which these organisms may have on the environment.

For the above reasons, and because of the particular threats which it poses, it is recommended that *C gariepinus* should only be cultured in catchments in which it naturally occurs.

THE LIFE HISTORY STYLE OF *CLARIAS GARIEPINUS*

The sharptooth catfish is an efficient opportunist and survivor which is well equipped to exploit whatever resources are available. They are typical altricial fish (Bruton 1986) which produce a large number of small young and exhibit no parental care. The parental investment and risk per young is therefore relatively low. This tactic is optimal for a fish which lives in an unpredictably perturbed ecosystem. The phenotypic plasticity of the sharptooth catfish is nevertheless high and they are able to adjust their life history style in accordance with the requirements of the environment. It is likely that the main life history adjustments made will be to the protein content of the yolk, the size and age at first maturity and to the growth rate. We are currently modelling the life style of the catfish from an ecological perspective in order to be able to predict the effects of changes in environmental factors.

USING NATURAL HISTORY INFORMATION IN AQUACULTURE

Our fairly good knowledge of the natural history of *C gariepinus* should allow us to culture this species more efficiently. Knowledge of the breeding and feeding behaviour of catfish has already been used to good effect in aquaculture. Some additional suggestions are given below:

1. In order to reduce stress and optimize the growth of the larvae and juveniles, it is advisable to construct ponds which have convoluted shorelines which provides a wealth of microhabitats as well as protection from predators. Shade cloth or mist nets could also be suspended along the edges of the ponds to provide shelter.

2. It is more important for fingerling ponds to have a high substrate:water volume ratio than to have a high volume of water. These ponds should therefore be shallow and wide rather than deep and narrow in order to optimize bottom foraging.

3. Broodstock and adult grow-out ponds, on the other hand, should be sufficiently deep to provide a refuge from aerial predators as well as from high light levels, which may cause stress.

4. In order to make maximum use of the water volume in the latter ponds, shelters and refuges should be introduced in the form of small artificial reefs of tubes, pipes and plastic containers, as is done in channel catfish culture. Smooth, nonabrasive materials should be used so as to minimize damage to the catfish. The artificial reefs should be buoyed for easy recovery prior to netting the pond. The use of tyres, concrete blocks and airbricks should be avoided as they are too difficult to remove from the pond.

5. The placement of catfish in ponds under intensive culture conditions removes them from the natural environment which is subject to a variety of checks and balances. Every effort should therefore be made to reduce stress levels arising from physical damage, physiological imbalances, cannibalism, the unnatural clumping of individuals of different sizes (which would normally live apart in nature), low quality food, overstimulation, constant disturbances or predation by birds.

6. Catfish throughout the world have well developed auditory, chemical and electric senses, and it is highly likely that the sharptooth catfish communicates intraspecifically using these senses, especially prior to spawning. *Clarias batrachus* has been shown to produce sounds by stridulations between the basal bulb of the pectoral spine and the wall of the cleithral socket, as well as by rubbing together the upper and lower bands of the pharyngeal teeth (Goel 1966). Unpublished research by the writer has revealed that *C gariepinus* has the same capability. Pheromones (hormones released into the external environment) may play a crucial role during courtship and mating, as they do in the channel catfish. Todd et al (1967) and Todd (1971) found that the bullhead *Ictalurus natalis* has a "complex chemical language with which it communicates individual identity, status, aggression, or submission, and reproductive state". It is necessary for us to study these nonvisual forms of communication in catfish so that we can eventually use them to our benefit in aquaculture. It should be possible, for instance, to attract catfish to feeding stations or traps, to induce or retard the development of the gonads or to reduce stress by sending out auditory, chemical and electrical signals.

CONCLUSION

Clarias gariepinus is one of the most widespread and adaptable fish in Africa and one of the most useful to man. It is eaten by more African people than any other freshwater fish and its expanding use in aquaculture will further increase its usefulness. It is also a fascinating animal for academic studies on developmental biology and physiology. I predict that it will soon be more widely cultured in other parts of the world as well.

ACKNOWLEDGEMENTS

I am grateful to the organizers of the CSIR Catfish Workshop for the opportunity to prepare this paper, and to Wynand and Marie-Tinka Uys for their hospitality during the workshop. Pete Britz and Tom Hecht are thanked for their comments on the manuscript.

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CHAPTER 2. AN OVERVIEW OF THE DEVELOPMENT OF CLARIID CATFISH CULTURE, WITH PARTICULAR REFERENCE TO SOUTHERN AFRICA

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INTRODUCTION

The African sharptooth catfish, *Clarias gariepinus*, is in many senses a remarkable beast (see also Chapter 1), a statement immediately justified considering its phenomenal natural distribution, which ranges from the Cape Province in South Africa throughout Africa into Asia-minor (Teugels 1986). This air breathing (Moussa 1957) clariid species exists in diverse environments, ranging from temperate to tropical, and is represented in a correspondingly diverse array of aquatic faunal assemblages, from the species poor Orange River system (Skelton 1986) to species-rich Lake Malawi (Fryer and Iles 1972). Natural history studies (Greenwood 1955, 1957; Groenewald 1964; van der Waal 1972; Clay 1977, 1979, 1981; Bruton 1978, 1979a,b,c,d; Quick and Bruton 1984) have shown that *C Gariepinus* is an extremely hardy and adaptable animal, efficiently able to exploit a wide variety of both animal and plant protein, under diverse environmental conditions. Furthermore, it is able to withstand adverse environmental conditions and habitat instability (see Chapter 1). The animal is highly fecund (Greenwood 1955; van der Waal 1972, 1974, 1978; Hogendoorn 1977; Bruton 1979a; Clay 1979). As pointed out in Chapter 1 spawning usually takes place after rain with rising water levels (Greenwood 1955, 1957; Holl 1966, 1968; Spinage 1971; Bowmaker 1973; Bruton 1979a). Hatching, although temperature dependent, occurs approximately 24 hours after fertilization at 24 to 26°C (Greenwood 1955; van der Waal 1972; de Kimpe and Micha 1974; Richter 1976; Bruton 1979a; Viveen et al 1985). The offspring, by exploiting newly inundated environments which are usually rich in food, operate temporarily in what McArthur and Wilson (1967) term an ecological vacuum almost free from inter- and intraspecific interactions. However, density effects do lead to competition for cover and food which results in sibling cannibalism (Hecht and Appelbaum 1988). Considering the above it is not surprising that this ubiquitous fish is perhaps the most important individual species in traditional subsistence and feral African freshwater fisheries being estimated to comprise some 20% of the total catch (Clay 1977).

Perhaps the most exciting feature of the catfish in terms of aquaculture is its potential for highly intensive culture without prerequisite pond aeration or high water exchange rates, necessary for the intensive culture of other species (Sidthimunka 1972; Areerat 1987; Huisman and Richter 1987). This type of culture is primarily facilitated by the catfish's air breathing ability and tolerance of poor water quality (Sidthimunka 1972; Babiker 1984; Clay 1979; Huisman and Richter 1987 and Chapter 1). The unique potential of air breathing catfish for intensive culture is illustrated by production statistics from Thailand where yields ranging from 12,5 to 100 tons ha^{-1} yr^{-1} are obtained in static water ponds (Panayotou et al 1982; Sidthimunka 1972; Areerat 1987). Such figures stand in marked contrast to intensive channel catfish (*Ictalurus punctatus)* culture where maximum yields in stagnant ponds are in the order of seven tons ha^{-1} yr^{-1}, if mechanical aeration is employed (Wellborn and Tucker 1985).

CULTURE

Several species of the genus *Clarias*, mainly *C gariepinus* (= *C lazera* Teugles 1986) and others, and their closely related Asian counterparts *C batrachus* and *C macrocephalus* adapt well to artificial environments, and have rapidly gained status as premier aquaculture species. Established catfish culture industries exist in Thailand (Sidthimunka 1972; Areerat 1987), Taiwan (Chen 1976) (although on a very limited scale, T Hecht personal observation) and the Philippines (Carreon et al 1976, and developing rapidly in several African countries eg South Africa, Zambia, Zimbabwe, the Central African Republic, Ivory Coast, Cameroon, Kenya, Egypt, Nigeria and Zaire (Hecht 1985), as well as in Europe, particularly in the Netherlands and in Belgium (Huisman and Richter 1987; Wray 1987).

In contrast to fish with a longer tradition of culture (eg carp and salmonid species), research into the biology of *C gariepinus* has a relatively recent history, beginning in the 1950's (Greenwood 1955, 1957). Greenwood's early work to a large extent stimulated the interest in the aquacultural potential of the species, although Hey (1941) already achieved a certain measure of success with breeding and growth experiments at the Jonkershoek Fish Research Station in the Cape Province. The understanding of the biology and culture of *C gariepinus* has developed rapidly and the number of catfish related publications have increased exponentially, covering diverse research interests. Most publications have been aquaculture related reflecting the rapid development of the technology of its culture.

The initiation of intensive research programmes on *C gariepinus* culture began in Egypt in the 1960's (El Bolock and Koura 1960; El Bolock 1969, 1973, 1975, 1976; Imam et al 1970; Aboul-Ela et al 1973). Since the early 1970's the research impetus spread to various other African countries, viz, the Central African Republic (C.T.F.T. 1972; Hastings 1973; de Kimpe and Micha 1974; Micha 1971, 1972, 1973, 1975; Kelleher and Vinke 1976; Richter 1976), Cameroon (Hogendoorn and Wieme 1975; Hogendoorn 1977, 1979, 1980, 1981, 1983; Hogendoorn and Vismans 1980; Hogendoorn and Koops 1983), South Africa (van der Waal 1972, 1974, 1978; van der Waal and Polling 1984; Schoonbee et al 1980; Hecht 1981, 1982, 1985; Hecht et al 1982; Bok and Jongbloed 1984; Uys 1984; Uys and Hecht 1985, 1987; Steyn et al 1985; Uys et al 1987; Britz and Hecht 1987; Steyn and van Vuuren 1987; Britz in press) and to a lesser extent in Kenya (Christensen 1981a,b), Zimbabwe (Clay 1977, 1979, 1981), Zambia (Hecht and Lublinkhof 1984; Hecht 1985) and Nigeria (Agunbiade 1977 and others). The earlier work of de Kimpe, Micha, Richter and Hogendoorn in central Africa also led to an impressive research output in the Netherlands (see Huisman 1986; Huisman and Richter 1987), particularly at the University's of Wageningen and Utrecht. Recently, the journal Aquaculture dedicated an entire issue (Volume 63, 1987) to research papers on *Clarias* species.

FRY PRODUCTION

The most urgent problem encountered during the development of the industry in South Africa, and elsewhere, has been an inadequate production of fry. This factor has been cited as one of the primary reasons retarding the development of commercial catfish production throughout Africa (Kelleher and Vinke 1976; Hogendoorn 1977; Hecht 1985). Early attempts at fingerling production involved either natural or controlled spawnings in ponds or tanks (van der Waal 1972, 1978; de Kimpe and Micha 1974; Nugent 1975; Micha 1975; Kelleher and Vinke 1976; Richter 1976; Hogendoorn 1977). Larvae were stocked directly into ponds without any intermediate nursing. Although good growth rates were obtained, unacceptably high mortalities occurred, ranging from 32,5 to 99,8% (Kelleher and Vinke 1976; Hogendoorn 1980). The major causes of mortality were cited as cannibalism, lack of adequate nutrition, and predation by the African clawed toad, *Xenopus laevis* (van der Waal 1972, 1978; Richter 1976; Kelleher and Vinke 1976; Hecht 1982, 1985). In view of these problems associated with the semi-extensive rearing of fry, several workers independently promoted the idea that an adequate supply of fry could only be realized through the development of intensive hatchery rearing techniques (Richter 1976; Clay 1977; Hogendoorn 1979; Hecht 1985).

The development of intensive fry rearing procedures for this species forms part of a worldwide trend towards controlled seed production (EIFAC 1976; Huisman 1976; Coche and Bianchi 1979); This is because an inadequate supply of fry has almost universally been a major limiting factor in the development of the large-scale culture of various species. The evolution of intensive fry rearing techniques usually involves the development of a) artificial spawning procedures, followed by b) the development of suitable larval feeds, and c) the creation of optimal artificial environments in hatcheries (Shehadeh 1979). The major breakthrough facilitating the development of modern aquaculture was the discovery that most species could be spawned artificially by means of hypophyzation (the injection of pituitary gland homogenates or extracts) (Bardach et al 1972; Huisman 1982). For example, the artificial hormone induced spawning of carp has facilitated its culture on a commercial scale in temperate areas such as Israel where natural spawning is less predictable (Bardach et al 1972; Hepher and Pruginin 1977). Intensive rearing procedures, in essence, offers the culturist greater control over fingerling production, eg:

- the time of spawning can be controlled by the culturist, thus work can be planned in advance;
- induced spawning eliminated environmental variables, ie spawning area, temperature, light and other climatic factors;
- fish that will not spawn naturally can be induced to spawn;
- culture ponds can be stocked with fry that are uniform in age and size;
- disease transmission from broodstock to offspring, and predation by adults is minimized;
- prophylaxis and treatment of disease is greatly facilitated;
- size grading of batches of juveniles is easily performed minimizing sibling cannibalism;
- hatchery rearing eliminates losses due to natural predators; and
- more efficient management is possible with regard to feeding, inventories, growth rate data and mortality records.

Artificial spawning

Initial efforts by van der Waal (1972, 1978) and Hogendoorn (1977) to artificially spawn, strip and incubate the eggs of *Clarias gariepinus* paved the way for the intensive rearing of larvae. Artificially induced spawning using *C gariepinus* pituitaries was first carried out by van der Waal (1972). Although hypophyzation using *Clarias* pituitaries offers a reliable and convenient method of induction (van der Waal 1972; Richter 1976; Carreon et al 1976; Hecht et al 1982; Viveen et al 1985) most research efforts have, however, concentrated on the use of other agents to induce spawning. Carp pituitaries have proven to be an effective inducing agent (Hogendoorn 1977; Hogendoorn and Vismans 1980), however, the use of other synthetic hormone treatments such as DOCA (desoxycorticosterone-acetate) (de Kimpe and Micha 1974; Hogendoorn and Wieme 1975; Micha 1975; Pham 1975; Richter and van den Hurk 1982), human chorionic gonadotropin (HCG) (Eding et al 1982) and Progestagen (Richter 1975) have met with limited success. Recent experimental work has shown that a pimozide/ LH-RH combination is an effective means of inducing spawning (De Leeuw et al 1985; Richter et al 1987). Pimozide is not, at this stage, commercially available and has not yet been approved for use on fish (Richter op cit). for the foreseeable future, however, hypophyzation remains the only realistic alternative for the commercial culturist in Africa where commercial hormone preparations are not readily available.

Further developments with regard to artificial propagation have been the cryopreservation of sperm (Steyn et al 1985; Steyn and van Vuuren 1987) and handstripping of males (van der Waal and Polling 1984). Sperm preservation would also facilitate genetic selection and eliminate the uncertainties involved in spawning, caused by the seasonal nature of male gonadal development. Furthermore, the necessity of sacrificing a male with each artificial spawning is eliminated. The handstripping of males has, however, met with limited success and is not, at this stage, considered a practical technique for large-scale propagation.

Early attempts by van der Waal (1972, 1978) to incubate eggs in Zuger funnels failed due to the adhesive nature of the eggs. A good survival of eggs was, however, obtained by incubating them in a monolayer on fine mesh, (van der Waal 1972, 1978) or in plastic trays in flowing water (Hogendoorn 1977). Schoonbee et al (1980) developed a technique for removing adhesiveness using a modified Woynarowich solution (Woynarowich 1962), thereby facilitating successful incubation of eggs in funnels. Subsequent experiene at the Rhodes University hatchery (unpublished) and elsewhere has shown that the incubation of eggs on series of vertical gauze screens, without removal of egg adhesiveness, is the most effective method of egg incubation.

Larval and early juvenile feeds

The development of dry larval feeds for *C gariepinus* was a major breakthrough facilitating the intensive large-scale rearing of larvae (Hecht 1981, 1982; Uys 1984; Uys and Hecht 1985), as the collection and/or culture of large quantities of live organisms as feed is a cumbersome and unreliable process (Appelbaum 1977). Hecht (1981, 1982) showed that a dry feed (torula yeast and fishmeal) or torula yeast in combination with live feed (*Daphinia* species) was superior to live feed alone. The dietary requirements of *C gariepinus* larvae were investigated in greater detail by Uys (1984), culminating in the formulation of an artificial dry larval feed for the intensive rearing of the larvae (Uys 1984; Uys and Hecht 1985). Using this diet in combination with live zooplankton resulted in a significantly faster growth rate than if the larvae were fed on live or dry feed alone. These findings appear to contrast with those found in the Netherlands' laboratories which recommend the use of live feed only. Considering the results obtained by Hecht and Appelbaum (1987) in larval growth trials in Israel and on comparing these results to those found by other workers it becomes quite clear that a combination of dry and live feed is the optimal from a cost and effort/benefit point of view. Adequate quantities of live feed for the rearing of larvae and early juveniles might not be a problem when rearing small numbers of larvae for experimental purposes or for the production of only a few tons of market size fish. However, the problem becomes acute when for example one hatchery rears in the region of some four million larvae to stocking size fingerlings during a three to four-month period. More recently, decapsulated *Artemia* cysts have successfully been used as a dry larval feed (Verreth and Den Bieman 1987; Verreth et al 1987). However, the relatively high cost of this diet in comparison to the yeast/fishmeal based diet formulated by Uys (1984) used in combination with *Daphnia*, favours the use of the latter. An adlibitum feeding regimen has also been recommended by several authors. A constant availability of food has furthermore been shown to minimize cannibalism (Hecht and Appelbaum 1988).

Environmental hatchery requirements

Successful hatchery rearing of larvae depends primarily on nutrition, disease prophylaxis, and optimum environmental conditions (Shehadeh 1979). Most of the earlier work focused on the artificial breeding and nutrition of catfish larvae, and until recently very little was known about their environmental requirements. This research need had been identified by several authors (Hoggendoorn 1979; Safriel and Bruton 1984; Hecht 1985). Disease has fortunately, up to the present, proven to be a relatively minor problem in the intensive rearing of *C gariepinus* larvae (van der Waal 1972; Huisman and Richter 1987; see also Chapter 9). Parasitic monogenean trematode and *Ichthyopthirius* infections can, however, lead to mass mortalities under hatchery conditions.

The effects of key environmental factors on growth, survival and aspects of the behaviour of *C gariepinus* larvae and juveniles have now also received attention. In our laboratories a strong emphasis has been placed on the interpretation of the observed responses in relation to the natural history of the animal (Hecht and Appelbaum 1988; Britz 1988; Britz and Pienaar in press).

Experimental attempts at controlled larval rearing under artificial environmental conditions, using various forms of zooplankton as feed, produced mixed results (van der Waal 1972; Jocque 1975; Pham 1975; Hogendoorn 1979, 1980; Hogendoorn and Vismans 1980). Investigations into the large-scale production of *C gariepinus* fry were initiated by Hecht

(1982). Hecht (op cit) successfully reared larvae at high densities (250 to 300 per litre) with low mortality (2,7%) using relatively high water exchange rates 200 litres per hour), in plastic bins (1 150 X 1 000 X 680 mm) maintained at 290 litre capacity.

PRODUCTION

Over the last decade the South African research effort on *Clarias* culture has focused primarily on the various aspects of seed production. Very little work has, however, been undertaken on production during the grow-out phase. Nevertheless some work has been done on the subject by van der Waal (1978), Bok and Jongbloed (1984) and Uys (unpublished) in South Africa, Hastings (1973) and Clay (1979) in the Central African Republic, El Bolock (1975) in Egypt and by Hecht and Lublinkhof (unpublished) in Zambia, as well as by the Dutch at the Agricultural University of Wageningen. The work by the above researchers was undertaken under widely different and therefore incomparable conditions. Some of the production figures are summarized in the table below.

Jannsen (1983) reports that small-scale farmers in the Central African Republic achieve production levels of just over 26 tons ha^{-1} yr^{-1}. While these production figures are encouraging we are of the opinion that greater yields could be obtained. Similarly the results of production trials under closed system conditions achieved by the Dutch and summarized by Huisman and Richter (1987) are also encouraging, particularly since high stocking densities have successfully been employed. However, the technology and the scale of operations developed in the Netherlands are not suitable for conditions in southern Africa. For this reason a programme to determine the optimal stocking density as well as the effect of stocking density and other abiotic factors on feed conversion efficiency and production of catfish has recently been initiated.

Production levels on South African catfish farms presently vary between 25 and 40 tons ha^{-1} yr^{-1} with feed conversion ratio's between 0,95 and 1,3. The time to rear fish to market size is largely dependent on temperature, feed quality and ration. Under optimal conditions fish can be reared to about one kilogram in six to nine months (this excludes of course the fast growing "shoots" which can reach one kilogram in little over two months).

CONCLUSION

The preceding discussion underlines the necessity for fundamental research into the biology of an organism, for the development of techniques for its culture.

Presently the technology for *Clarias* seed production has been developed to a stage where it can no longer be regarded as a major factor impeding the development of commercial *Clarias* culture. Similarly the development of earthern pond culture techniques at relatively high densities has progressed to a stage where catfish can now be cultured on a profitable basis. The development of this technology has been extremely rapid in comparison to other cultured finfish, and reflects the rational and committed research base from which it has proceeded. One of the key

TABLE 2.1. *Clarias* pond production in Africa

Country	Pond size (m^2)	Stocking density/ha	Feed	FCE	Yield (kg/ha/ time)
Central African Republic (Hastings 1973)	320	20 000	Bonemeal, vegetable-by-products	0,7-3,6	12 786/yr
Central African Republic (Clay 1979)	-	-	Cotton seed-cake		16-18 000
Egypt (El Bolock 1975)	926	26 900	Chicken offal blood, bran	3,2	5 388/6m
Transvaal (van der Waal 1979)	300-1 400	54-170 000	Trout pellets	5,1-7,1	3 135/7m
E Cape (Bok & Jongbloed 1984)	200	10 000	Poultry manure (no feed)		1 069/5m
E Cape (Bok, unpublished)	200	20 000	Chicken guts		2 875/6m
Zambia (Hecht & Lublinkhof unpublished)	400	100 000	Brewery waste	1,2-2,2	65 000/8m
Kannemeyer (unpublished)	-	40 000	*Clarias* pellets		
Uys (unpublished)		100 000	*Clarias* pellets		

issues currently being investigated is the optimal stocking density at which catfish should be cultured. Considering the wide range of environmental tolerances of the species coupled with the fact that it is an obligate air breather and that no differences have as yet been obtained in the condition of the fish under low and "high" stocking densities, we predict that production figures in the future will greatly exceed our present maximum levels of 60 tons ha^{-1} 10 $months^{-1}$. While a basic research foundation has been laid, facilitating the intensive culture of *Clarias*, there exists a vast potential for improving and refining the technology. Such further development must, however, largely be the product of experience as the needs and nature of the developing industry become evident.

Apart from presenting an overview of catfish culture a secondary aim of this chapter was to provide a reasonably comprehensive bibliography on the subject.

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CHAPTER 3. SITE SELECTION, PLANNING AND POND CONSTRUCTION

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INTRODUCTION

For several reasons commercial catfish culture is capital intensive. The primary reason being the high cost of suitable land as those areas generally deemed suitable for catfish culture are at the same time prime agricultural areas. It is therefore essential that careful consideration be given to the selection of a suitable site. Upon having chosen such a site the next step is to carefully plan the physical development of the farm.

The aim of this contribution is to list and comment on those factors which have to be considered in choosing a site and to make some recommendations as regards the physical planning of the farm thereby minimizing risk which might be costly and ultimately result in a decreased return on investment.

SITE SELECTION

The primary objective in selecting a suitable site for a catfish farm should be to satisfy all physical, biological and infrastructural requirements for the operation to be successful. In reality this is rarely possible and a compromise is usually made regarding certain factors.

Primary considerations when selecting a site include climate, topography, water quality and quantity and soil type. Considerations of lesser importance, but which must nevertheless also be taken into consideration, include the regulations laid down by provincial nature conservancies, town and regional planning departments and the South African Bureau of Standards, agricultural water rights, markets, feed sources, technical services, labour and economic incentives.

Environmental requirements

Temperature is probably the most important environmental requirement and should be given a high priority when choosing a site. It has been established that the optimum temperature for the growth of *Clarias gariepinus* is 30°C. The upper and lower limits for economical growth rates are between 34 and 24°C. Temperatures below 10°C and above 40°C may be lethal. It has also been established that at optimum temperatures *Clarias* can be grown to marketable size (one kilogram) in six to eight months. When selecting a site it is important to establish that temperatures remain within the optimum range for at least eight months of the year. Temperatures should not exceed the upper and lower optimal limits for prolonged periods, particularly if fry and fingerlings are to be produced on the site. It is obviously possible to consider a site with a shorter growing season (eg the Transvaal highveld), but consideration would have to be given to the importation of fingerlings from warmer areas, so that the growing season is used to best advantage.

Water quality and quantity

It is important to ensure that the quality of water supplying the proposed site conforms to general aquacultural standards as regards chemical pollutants and suspensoids. One should also be certain that there is no possibility of the water supply becoming polluted at any stage, particularly from agricultural runoff, containing pesticide or herbicide residues, or industrial waste. Purified sewage effluent, however, is very suitable. The reliability of the supply should also be established.

The envisaged size of the proposed fish farm must be considered in order to establish whether the available water will be sufficient for long-term requirements. Local experience has shown that a flow rate of between two and six litres per second is required per hectare to produce in the region of 40 tons per ha^{-1} yr^{-1} (Uys unpublished). In the Philippines catfish are, however, successfully reared in stagnant ponds, with yields in excess of 100 tons ha^{-1} yr^{-1}. Further research is currently being undertaken at Rhodes University to quantify expected yields from stagnant as well as flow-through ponds.

Topography and soil type

The ideal size of production ponds is between 1 000 and 2 000 m^2. The optimal slope to build such ponds is 1:20 m. Ideally all ponds should receive water by gravity feed. Similarly the discharge should also be under gravity. This circumvents the necessity of utilizing expensive pumping equipment. If water is to be pumped, it must obviously be cost effective.

It is also important to consider the past usage of the land as residues of toxic chemicals, particularly pesticides and herbicides, may still be present in the soil.

A soil sample should also be analysed to determine its water permeability. Soil that is too sandy for dam building purposes can be modified. This may, however, prove a costly exercise and its justification will have to be weighed-up against other factors. Ideal soil types include silty clays, clay-loams and loams. Land with rocky outcrops should be avoided as should shale, sand gravel and limestone areas. It has been our experience that, with careful construction, ponds can be built successfully on sandy soils. This will be dealt with in the section on pond construction.

Statutory regulations

The various regulations affecting potential fishfarmers are reviewed in Chapter 13. It is important to establish what effect, if any, these regulations might have on the development of a proposed site. For example, *Clarias gariepinus* does not occur in the majority of rivers in the Cape Province. The siting of a catfish farm in the catchment area of such rivers would probably infringe upon regulations laid down by the Province regarding the translocation of species between catchments.

Bearing in mind that aquaculture in the Republic of South Africa is defined as an industry, it is important to establish the water rights of the site. The implications of the industrial definition of aquaculture are that a) water made available for agricultural purposes may not be used for aquaculture without the consent of the relevant authorities and b) the amount of water removed from a river must be returned to that river and conform to industrial effluent standards. Special attention must also be given to Water Court rulings.

Feed source

Consideration must be given to the proximity of feed manufacturers and/or to the availability of feed ingredients in the area. Transportation of both feed and feed ingredients is costly and thus the closer the source the better.

Markets

The proximity of suitable markets is important. Consideration must also be given to the type of market at which the enterprise is aimed. It is simpler and cheaper to market fish directly from the farm. However, this is rarely possible and it may be financially more rewarding to process the fish and to send it to a more sophisticated market. The present marketing of catfish is difficult and is discussed in Chapter 8.

Labour

The cost of labour increases the closer the site is to urban areas. This factor must, however, be seen in the light of other advantages gained by being close to urban areas, eg the proximity of sophisticated markets and lower transport costs.

Proximity to other fish farmers

The proximity to other fish farmers is important as many benefits may accrue. For example, joint processing and marketing, the possibility of the establishment of a joint feed manufacturing facility and the reduction of costs through sharing of breeding facilities.

Services

A suitable electricity supply is of the utmost importance. The amount of electricity required will be determined by various factors eg, whether water is gravity fed or needs to be pumped and whether feed production equipment is to be installed on the farm. Proximity to well equipped hardware suppliers, such as farmers cooperatives should be considered, as the requirements are usually somewhat unconventional.

Regional development financing

Consideration must also be given to the various development incentives given by the South African government as well as by the governments of the National States. These include labour and rail tariff rebates, and in some instances assistance with the purchase of land and development costs.

Geographic zones for catfish farming

There are several regions which may be considered suitable for catfish farming in South Africa (Figure 3.1). The major constraint with all theareas is the fact that they are also prime irrigation areas in the country. Land prices, therefore, tend to be relatively high. However, catfish farming can be practised economically on much smaller farms than those suitable for irrigation purposes. These farms should be sought out.

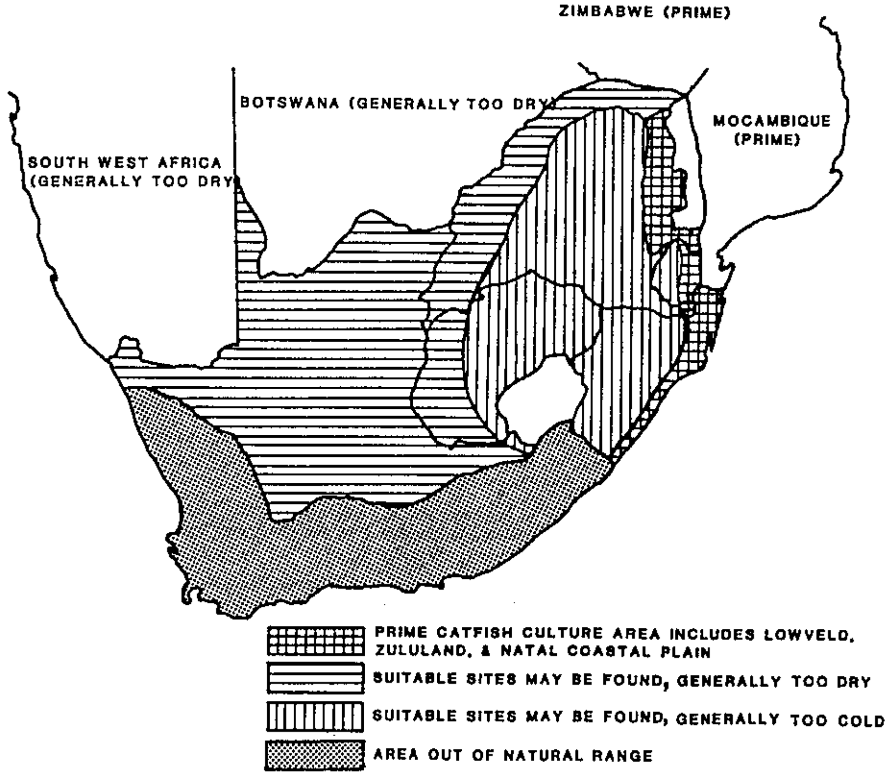

FIGURE 3.1 The suitability of various regions for the culture of sharptooth catfish within its natural distributional range.

The following areas were identified as having a high potential.

1. The Eastern Transvaal Lowveld from the Swaziland border in the south to the Zimbabwe border in the north, particularly on the Komati, Crocodile, Blyde, Olifants, Letsitele and Letabe Rivers and their associated irrigation networks. Other rivers might at first glance appear to be suitable but may have such limiting factors as for example the occasionally high cyanide content of the Noordkaap River, near Barberton, as a result of early mining practices.

2. The northern Transvaal north of the Soutpansberg. Particularly along the irrigation schemes of rivers such as the Mutali and the Njelele. Water availability may, however, be a problem in this area.

3. Areas in the Transvaal Highveld are marginal although suitable for grow out purposes. However, the early summer temperatures are usually too low to facilitate grow-out in a single season.

4. The northern Natal and Zululand coastal belt. This area has good potential as a prime *Clarias* farming area, but is limited by two factors, viz the distance from sophisticated markets and the fact that the local black population does not readily buy freshwater fish. This appears to be due to the fact that they themselves are not accustomed to paying for fish. A careful cost/benefit analysis would therefore have to be undertaken before deciding to set up a catfish farm in this area.

5. Many areas in the western parts of South Africa, eg the western Transvaal, the Orange Free State and that area of the Orange River drainage system which falls within the Cape Province may well be suitable from a temperature point of view, but may lack an adequate supply of water. However, these are areas where catfish farming would definitely be viable.

At present the eastern Transvaal regions are considered to be the prime areas for the following reasons: a) proximity to large markets both in the cities and the rural areas, b) ideal climatic and water conditions.

It nevertheless remains advisable to consult an expert in the choice of a particular site. Also, an "Expert Choice System" has been developed which can be used as an aid for decision making (Dean 1987). This programme works on DOS on IBM compatible microcomputers. However, this package should not be viewed as a fool proof method for site selection. It is basically designed as a tool for expert use. Prospective catfish farmers should therefore consult experts before a final decision is made.

SITE PLANNING

At this stage certain decisions should already have been made regarding the size of the operation, whether or not a hatchery is to be constructed, whether or not food is to be manufactured on site or brought in, and so on. Once these decisions have been taken site planning can commence. It is obviously important that the overall layout be considered with full consideration given to the interaction of the various requirements for fish production. It should be borne in mind that the more compact the layout is, the easier it is to manage, and the more economic its usage. The object is therefore to out lay the site to achieve maximum efficiency with regard to the following operations:

- fish will be spawned in a hatchery, which will require broodstock holding facilities;

- fry will be transferred to nursery ponds, after which they will be size sorted and placed into production ponds or sold;

- the transfer of fish from one type of pond to another should be done as quickly as possible and the layout must facilitate this process;

- fish have to be fed at regular intervals, therefore the locality of the feed store and the supply of feed is important;

- predators, both human and otherwise, may be a persistent problem. Through careful planning their activities can be reduced significantly;

- Cognisance has to be taken of the necessity to move fish on the site between ponds and from the site to market. Vehicular access to all ponds is therefore necessary.

It is strongly recommended that the prospective fish farmer visit various fish farms around the country, particularly those farming *Clarias*, in order to gain a better insight into what is required for such an enterprise.

Buildings

Hatchery. The design of a hatchery has been dealt with in Chapter 4.

Feed store and feed manufacturing area. A feed store is essential, both for feed ingredients, if the feed is to be manufactured on site, or for bought pelleted feeds. The store should be rodent proof and should provide a cool dry area for the storage of feed. The feed manufacturing area should be large enough to accommodate all the equipment required, including a hammer mill and a pelleting machine, and it should be well ventilated, as the process of feed manufacturing is dusty.

Abattoir. Regulations governing the construction of a fish abattoir are extremely complex and strictly enforced by the controlling bodies eg SABS and the local health authorities. It is therefore advisable to consult with these bodies and with owners of existing fish abattoirs prior to designing.

POND CONSTRUCTION

Earthen ponds are more suitable for holding broodstock, for the rearing of fingerlings and as grow-out ponds than are concrete ponds or raceways. Concrete ponds result in serious abdominal abrasions particularly in adult fishes.

Two methods of pond wall, or dyke construction are commonly employed. The recommendations made here should be regarded purely as guidelines. The advice of a civil engineer should be obtained. A dyke may simply be pushed into position by a bulldozer. The result is a steep sided, inverted "V"-shaped wall. This type of wall tends to be very narrow at the top and is insufficiently compacted. The advantage of this type of wall is that it is relatively cheap to build, but in the long run could prove to be extremely costly, apart from the fact that such pond walls are extremely inconvenient from a work point of view.

Despite the higher initial cost it is recommended that a more substantial wall be built. Such a wall should have an inside slope of 1:2 to 1:4 and an outside slope between 1:1,5. The top of the wall should be approximately 2,5 m in width. During the building process the soil should be compacted in layers not exceeding 20 cm, using either a front-end loader or mechanical compactor. Figure 3.2 is a schematic diagram of such a pond wall. This type of wall is inherently stronger, and requires less freeboard. Once grassed it will withstand limited overflowing, and has the added advantage that a road may be constructed on it.

Each pond must have an outlet at its lowest point, which should be put into position before dam construction begins. This outlet can have many forms, including the traditional monk outlet. An outlet which has been used successfully by ourselves is simply a 160 mm diameter pipe for larger production ponds, and a 110 mm pipe for smaller nursery ponds, placed under the wall, with an elbow and an upstand pipe on the outside. The upstand pipe on the outside regulates the water level. It can also be swivelled to a horizontal position to drain the pond. Ordinary industrial plumbing fittings can be used for this type of outlet. In addition, fittings can easily be modified for making the necessary screens needed to keep smaller fish in the ponds.

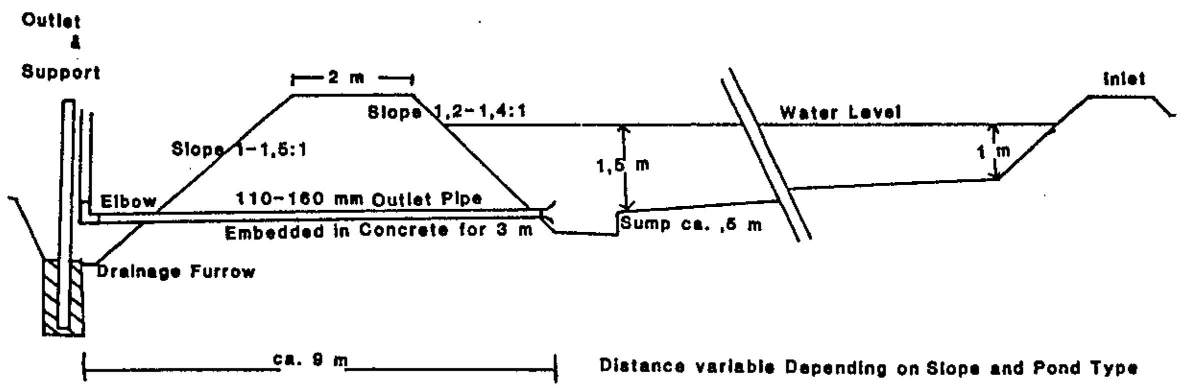

FIGURE 3.2 Schematic longitudinal section of an earthern pond.

It is important to note, however, that any pipe placed under the wall should be embedded in concrete (Figure 3.2) and soil should be well compacted around the structure. Failure to do this may result in seepage around the pipe, which could ultimately result in a "wad" of soggy soil being forced out, causing the collapse of the wall. A monk is usually constructed of concrete. It is built on the inside of the dam above the outlet pipe, to which it is connected. It stands approximately 1,5 m high. The inside walls of the structure have grooves from top to bottom into which wooden slats can be fitted, thereby controlling the depth of the water. The space between the wooden blocks are packed with clay or saw dust in order to prevent leaking. A screen may also be slid into the grooves in order to prevent fish from escaping. The obvious disadvantage of a traditional monk type outlet is that oxygenated water is removed from the surface. Modifications can, however, be made to draw off water from the bottom.

It is also advantageous to construct a simple drainage system on the bottom of the pond. This ensures that no pools of water remain below the outlet pipe and also helps to channel fish to the outlet when draining the pond.

Inlets to all ponds should be constructed in such a way that unwanted organisms, such as platannas (*Xenopus laevis*) and "trash" fish are prevented from gaining access to the pond. This can be achieved by placing a net bag or screen over the inlet pipe or a screen in the inlet canal.

It is extremely important to secure the ponds against platannas and otters. Platanna proofing is achieved either by the erection of a net approximately 30 to 50 cm high around the ponds, or by constructing a concrete wall, of a similar height, around the ponds. The second option is more costly but will be more secure and permanent. It is important to note that both structures should begin at least 10 cm below the surface. Platanna proofing is only important around ponds which will hold fish under 50 g. Otter proofing is best achieved by constructing an electrified fence around the perimeter of the ponds. Three strands, 100 mm apart, is all that is necessary, with the middle strand being an earth wire and the top and bottom strands being live. A low ampere, high voltage system of the type normally used for livestock control is ideal.

The construction of ponds in sandy or gravel soils with rocky outcrops requires special attention. The rocky outcrops need to be broken up as completely as possible, particularly if a pond wall is to be built over them. Prior to building the pond wall it is necessary to dig a trench of the same width as the base of the pond wall. The soil for pond wall construction then needs to be mixed with bentonite to reduce seepage to an absolute minimum. Under these conditions it is also vitally important to compact the soil as well as possible. Provision should also be made that any seepage water be channellized and led into ponds lower down the slope in order not to exceed the allocated water quantity.

TYPES OF PONDS

Three types of ponds are required for successful catfish farming. Although the method of their construction is similar, they vary in depth and outer dimensions.

Broodstock ponds

These ponds should be constructed close to the hatchery and should not exceed one metre in depth in order for the temperature of the water in the ponds to rise as rapidly as possible during early spring. They should have a good water supply so that temperatures can be kept at reasonable levels at the height of summer. These ponds should be between 100 and 500 m^2. There should be an adequate number of these ponds to allow for the separation of broodstock obtained from different areas and to allow for genetic selection.

If it is not possible to construct broodstock ponds, large shallow portable plastic swimming pools, approximately three metres in diameter should be erected close to the hatchery. A common water source should supply these ponds and the hatchery. This will ensure that the broodstock fish are kept in water with the same temperature as the water in which the eggs will be developing.

Fingerling ponds

For ease of management the fingerling ponds should be between a quarter and half the size of the grow-out ponds ie approximately 250 to 500 m^2. Ideally there should be one fingerling pond for every four or five grow-out ponds. These ponds can also be used as broodstock holding ponds and as holding ponds for production fish, after sorting, prior to sale. It is essential that they receive an adequate and constant water supply. Prior to emptying these ponds and removing fish, all floating macrophytes should be removed to prevent fish becoming trapped as the water level subsides.

Grow-out ponds

Ideally these ponds should be between one tenth and one fifth of a hectare in surface area (1 000 to 2 000 m^2), and not more than 1,5 m deep at the deep end and one metre at the shallow end. Depending on the topography of the site, larger or smaller ponds can obviously also be constructed. However, the ultimate size of grow-out ponds is largely determined by the trade-off between larger water bodies, which are difficult to manage, and smaller more expensive water bodies which are more easily controlled (Chapter 6). Furthermore, some data (Hecht unpublished) show production figures in larger ponds to be lower in comparison to smaller ponds.

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CHAPTER 4. ARTIFICIAL PROPAGATION AND FRY PRODUCTION

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INTRODUCTION

A general paucity of juvenile fish for stocking into production ponds necessitated the development of artificial propagation and fry rearing techniques for most aquaculture species. In the sharptooth catfish culture industry, this development was necessary because the semi-natural methods of propagation used in early production trials were found to be inadequate for the mass production of fry on a commercial scale (van der Waal 1972, 1978; Kelleher and Vinke 1976; Richter 1976). As a result of intensive research performed over the last decade, fry production has developed into a highly controlled hatchery-based operation. Artificial propagation involves the selection and conditioning of broodstock, hormone induced spawning, handstripping of eggs, fertilization using sperm from sacrificed males, incubation of eggs and the rearing of larvae under controlled environmental conditions using formulated artificial feed supplemented with live feed. In this chapter the procedures currently employed for the production of fry are described in detail and guidelines for the layout of a hatchery are provided.

BROODSTOCK CONDITIONING

Due to the relative abundance of *Clarias gariepinus* in southern Africa, broodstock may be obtained with relative ease from many natural waters. Fish of between one and and five kilograms are the most practical size for artificial spawning. Smaller or larger fish may, however, also be used. Gillnets with a 90 to 130 mm stretch mesh size are most suited to catching fish in the one to five kilogram size range. Catfish reach sexual maturity between their first and third years at a size of 200 to 300 g upwards (Bruton 1979a and Chapter 1; Richter et al 1982). The relatively high fecundity of the catfish is an advantage with respect to its culture. Females in the one to five kilogram range may yield between 30 000 and 500 000 eggs (van der Waal 1972; Bruton 1979a, personal observations). Feral catfish display a seasonal reproductive cycle, with gonadal recrudescence occurring in the spring as water temperatures rise. Unlike many other fish species, their annual gonadal cycle does not appear to be influenced by photoperiod, but is primarily controlled by temperature (Richter et al 1987).

Broodstock may either be caught in a gravid condition in the wild, or brought to seasonal maturity in captivity. If fry are to be ready for stocking into production ponds early in the growing season, ie September/October when water temperatures rise above 20 to 22°C, the conditioning of broodstock is essential as wild stocks are not gravid this early in the summer. Under natural conditions catfish are usually found with ripegonads from November to April. Broodstock may be brought into spawning condition within a period of one month if the water temperature is raised to 5 to 28°C and the fish are fed a high protein diet (42 to 48%). The conditioning of broodstock should be initiated in August if fingerlings are to be ready for stocking purposes by October. It has, however, been found that fish spawned and reared at a constant temperature of 25°C under laboratory conditions, do not display a seasonal gonadal cycle and are gravid throughout the year (Richter et al 1987; van Oordt et al 1987). When such fish are spawned, gonadal recrudesence occurs within three months whereupon they may be spawned again.

The ripeness of a female is judged by the size of the abdomen (Plate 4) and the condition of the eggs. A gravid female has a visibly distended belly. However, because this may simply be a sign of a full stomach a sample of eggs should be examined to confirm the ripeness of the eggs. If the female is ripe it should be possible to extrude a number of eggs from the genital papilla by applying pressure to the abdomen. Alternatively, a one to two millimetre diameter canula can be inserted four to six centimetres into the genital papilla, and a small sample of eggs obtained by gentle suction on the end of the canula. Ripe eggs are translucent and ca 90% have a diameter greater than one millimetre. If the eggs have an opaque yellow and runny appearance reabsorption of the gonads has begun (usually as a result of a decrease or sudden increase in temperature) and it is too late to spawn the fish. The colour of ripe catfish eggs is variable and does not appear to reflect their condition. Egg colour may be shades of green, red or brown, and appears to be influenced by diet (Hecht unpublished).

It is generally not possible to judge the ripeness of male fish by means of any external examination. One or two males must therefore be killed, and dissected to reveal the conditions of their testes. The testes lie dorsally and to the rear of the abdominal cavity along with its associated seminal vesicles (Plate 6). The presence of ripe sperm in the testes is indicated by a white, opaque, milky colour extending from the distal margin into the body of the testis. Unripe testes are usually smaller and have a translucent colour. The testes of dissected males need not go to waste, as the sperm will remain viable for at least 24 hours in vitro in a 0,9% saline solution, if the whole testis is stored at approximately five degrees Centigrade (Hogendoorn and Vismans 1980).

HORMONE INDUCED SPAWNING

In southern Africa artificial spawning is most commonly induced by hypophyzation, which involves the injection of fish pituitary gland homogenate into the female to stimulate final egg maturation and ovulation. The gonadotrophic activity of the pituitary is ascribed to the action of the pituitary gonadotrophic hormone (GTH) which is synthesized and stored in the pituitary gland. GTH is normally released into the bloodstream in response to certain natural cues which induce spawning activity, such as rising water levels. In effect therefore, the practise of hypophyzation which introduces GTH directly into the bloodstream circumvents the natural cues required for ovulation. The use of pituitary homogenate is considered by some to be a relatively crude method of induction because pituitary glands are unbioassayed and may vary in potency with possible uncertainties with respect to dosage. In practise, the dosage of pituitary gland homogenate administered is generally higher than necessary to make allowance for their variable potency. The administration of a larger dose than necessary does not harm the fish or affect spawning success. Although a number of alternative treatments utilizing synthetic hormones have been developed to induce spawning in catfish (see Chapter 2), hypophyzation using catfish pituitaries remains the most practical alternative in the African context, due to the relative ease with which pituitaries may be obtained. Furthermore, synthetic hormonal preparations are usually expensive, not readily available, and (based on our experience) often less reliable.

The pituitary gland is situated at the base of the brain and methods for its removal are shown in Plate 2. Schoonbee and Swanepoel (1986) also describe a technique for the rapid removal of the pituitary gland. It is essential that pituitaries are removed immediately after the animal is killed. Pituitaries may be kept for two to three years if preserved either in absolute alcohol or are acetone dried.

A single injection of pituitary homogenate is required to induce ovulation. No primer of follow-up doses are required. The dosage required to induce spawning is one gland per female taken from a fish of equivalent weight during summer. If the glands are taken in early summer the dosage is increased to 1,5 per female. If the pituitaries originate from smaller or larger fish, the dosage is adjusted according to the weights of the donor and recipient fish. Pituitary glands are prepared for injection by homogenizing them in a small quantity (one millilitre per gland) of distilled water in a tissue grinder (Plate 3). The pituitary homogenate is then drawn into a hypodermic syringe and injected intramuscularly in the nape region. The injected volume should not exceed 1,5 ml per fish.

Following hypophyzation the females are placed separately into smaller holding tanks because of their aggressive behaviour which occurs prior to spawning. If catfish are kept communally in a confined space at this time, they severely injure and often kill one another. In addition, the tanks of hypophyzised females are covered with a firmly secured net to prevent them jumping out as a result of their vigorous prespawning activity.

HANDSTRIPPING OF EGGS

The latency period between hypophyzation and stripping is temperature dependent (van der Waal 1972; Viveen et al 1985). At 24°C the latency time is 12 hours. This period decreases to seven hours at 30°C, and increases to 18 hours at 21°C (Viveen et al 1985). Hypophyzation is usually carried out in the evening, so that the females are ready to spawn the following morning. If the females were underdosed or are not fully ripe, the interval between hypophyzation and stripping may be considerably longer than predicted (from one to 12 hours). It is therefore essential that the condition of the eggs be examined before stripping is attempted.

When the estimated time between hypophyzation has elapsed, the female is removed from the tank and held in a dry towel. If eggs are spontaneously extruded from the genital papilla, the fish is ready for stripping. If the eggs do not flow freely, the female is returned to the tank and examined hourly until ready for stripping. If the eggs flow freely, the loss of eggs is prevented by the immediate placement of the thumb over the genital papilla.

Two people are required to strip a female. The person performing the stripping holds the head of the fish with one hand and strips the eggs with the other (Plate 5). The second person holds the tail of the fish and the egg receptacle. The abdomen of the female is blotted dry to prevent water coming into contact with the eggs prematurely. The eggs are stripped into a dry plastic bowl. Stripping is effected by applying an even pressure down the abdomen of the fish (over the ovaries) towards the genital papilla using the thumb. The two ovaries lie parallel in the abdominal cavity, and the stripping action is therefore applied alternatively on the left and right sides of the abdomen to ensure complete extrusion of eggs. Traces of blood signify that the ovaries are empty. The stripped eggs are then weighed in order to estimate their total number. One gram of eggs contains between 500 to 700 eggs.

FERTILIZATION

A male is anaesthetized and sacrificed whereafter the testes are removed. The testes are slit along the distal margin using a sharp blade and the semen squeezed over the eggs (Plate 7). Eggs and semen are then gently mixed using a soft rubber spatula. A small quantity of water from the incubation trough is then added, and gentle stirring continued for another minute. The addition of water activates the sperm, and causes the eggs to swell and become adhesive. The swelling of the eggs causes the egg micropile to close.

EGG INCUBATION

One minute after the addition of water to the gametes, more water is added to almost fill the bowl, and a small quantity of eggs are spread over a gauze incubation frame (one millimetre mesh gauze) (Plate 9). If the eggs adhere to the gauze the process is continued using a series of gauze frames, which are placed vertically into the incubation trough. If the eggs do not readily adhere to the gauze frames, an interval of 30 to 60 seconds is allowed to elapse, so that the adhesiveness of the eggs may develop.

The incubation trough is supplied with a flow of at least five litres per minute of well aerated water. The eggs are maintained under low light intensity or even darkness. Direct sunlight is fatal to eggs. The optimum temperature range for incubation is 27 to 30°C. Eggs are, however, very tolerant of temperature fluctuations and will hatch successfully from 17 to 33°C. Hatching is temperature dependent and takes between 20 and 24 hours within the optimum temperature range). At temperatures below 23°C, mortalities are often high due to the increase in development time and the greater likelihood of fungus (*Saprolegnia)* infections.

The hatching of a batch of eggs is usually complete within three hours after the first embryos have hatched. The incubation frames are then carefully removed from the hatching trough in order to prevent the dislodging of the dead eggs and egg cases which promote fungal infections. The free-embryos (hatchlings) are photophobic (Britz 1988) and form aggregations on the bottom of the incubation trough. The free-embryos swim from the incubation trough into the larval rearing container. This movement is encouraged by darkening the area around the outlet of the incubation trough and by placing a light at the other end. By allowing the free-embryos to swim out of the incubation trough they are separated from the dead eggs and deformed or weak animals, and thereby minimizing health problems in the larval rearing container. When most free-embryos have swum over into the larval rearing container, the water supply to the incubation trough is shut off and the trough cleaned.

LARVAL REARING

The objective of a commercial hatchery is to produce the maximum number of fry in a minimum volume of water, in as short a time as possible. Efficient larval rearing depends primarily on feed quality and ration, feeding frequency and the provision of optimal environmental conditions as well as on the experience of the hatchery manager.

Feeding

Exogenous feeding commences on the second or third day after hatching, before the yolk sac is completely absorbed. *Artemia* nauplii in combination with a formulated dry feed (Uys and Hecht 1985) are used as a first feed. It has been shown that a continual supply of food produces the highest growth rates (Hogendoorn 1981; Uys 1984). In practise larvae are fed ad libitum by hand every two to three hours for 16 to 18 hours a day. Automatic feed dispensers, although previously only used on an experimental scale for catfish larval rearing, greatly streamline the feeding process. The larvae grow very rapidly after the start of exogenous feeding (about 100% of body weight per day). The ration of food should therefore be correspondingly high (>400% body weight per day). Ad libitum feeding results in food wastes accumulating in the larval rearing container. However, such wastes are generally not removed as they have been demonstrated to neither adversely affect the health nor the growth of the larvae (Britz 1988). The feeding of *Artemia* nauplii is terminated on the second or third day after the start of exogenous feeding when the larvae are large enough to ingest larger zooplankton (usually *Dapnia*) which are obtained from special plankton ponds. If an abundance of such live feed is available, a constant concentration of live feed organisms is maintained in the larval rearing container as this greatly enhances their growth rate.

The optimum particle size for the ingestion of dry feed has been found to be 2,2% of body length (Uys 1984). The particle size of the dry feed is therefore increased proportionately as the larvae grow. The dry feed formulated by Uys (1984) is composed primarily of torula yeast and fishmeal (for the full formulation see Chapter 5) and is relatively cheap in comparison to other alternatives such as *Artemia* eggs recommended by other authors (Verreth and den Bieman 1987).

Optimum environmental conditions

Due to their tolerance of wide environmental fluctuations, it is possible to rear larvae over fairly broad ranges of temperature, photoperiod, salinity and water quality. Should one or more of the environmental parameters deviate from the range of optimal growth, the survival of larvae is not usually seriously impaired. Optimum environmental conditions, for *Clarias gariepinus* larval rearing, have been defined by Britz (1988) as a series of optima with acceptable ranges of deviation for each environmental parameter:

Temperature - The optimum temperature for growth appears to be 30°C, however, temperatures in the range 26 to 33°C yield acceptable growth. At temperatures below this range, growth rates decrease but survival is still good (Britz and Hecht 1987).

Photoperiod - A 0L/24D photoperiod (continual darkness) appears optimal. Although larval growth decreases with longer light photoperiods, survival is good. In light conditions, the provision of cover enhances growth.

Salinity - A salinity range of 0 to 2,5 appears to be optimal, however, larval growth is acceptable up to 5 salinity and survival is good up to 7,5 .

Oxygen - Although the effect of oxygen on larval growth and survival has not been quantified, well oxygenated water is recommended. This is easily achieved by means of aeration or good flow rates.

Water quality - *Clarias gariepinus* display a high tolerance for ammonia with a 96h-LC50 = 2,3 mg/l NH_3. Under normal hatchery rearing conditions, ammonia does not appear to be a limiting or lethal factor. Furthermore, the cleaning of larval rearing containers appear unnecessary, because uneaten food and faeces do not appear to adversely affect water quality to an extent that is detrimental to the larvae.

Density - Growth is density dependent, ie the higher the rearing density of larvae, the lower their growth rate. The optimum density for intensive larval rearing must therefore be a compromise, determined by a cost-benefit analysis. A hatchery production model developed by Britz (1988) predicts that hatchery production will increase up to a density of 1 400 individuals per litre.

HATCHERY DESIGN

General

Because the objectives and material circumstances of most sharptooth catfish culturists differ in some way, it is not possible to provide a definitive hatchery design. It is essential, however, that certain basic requirements are fulfilled when designing and constructing a hatchery. Firstly, it must be established whether the building of a hatchery would in fact be cost effective. For the purposes of this discussion it is assumed that at current (early 1988) retail fingerling prices (10c each) it is not cost effective to build a hatchery and employ a hatchery manager, if the hatchery produces less than half a million fingerlings per annum. Secondly, when designing and siting a hatchery, particular attention must be paid to water quality maintenance, pathogen control and other factors which will reduce stress on the fish.

Hatchery size

The basic design provided here is for a hatchery which is capable of producing a million fingerlings in a spawning season of seven months (Figure 4.1). Furthermore, it is assumed that fry production will take place at a more or less constant rate over this period to fulfill the requirements of a staggered stocking programme (see Chapter 6). Further, if the required number of fry were to be produced over a short period of time, eg at the beginning of the season, costs would increase significantly because larger hatchery facilities would be required, which would be underutilized during the intervening periods.

Water quality

Ideally a site with good water quality should be chosen. It is possible to control water quality to a certain extent, however, this may be very costly depending on the type of treatments employed. For example, water quality may be altered by means of temperature control, pH control, settling of solids, filtering systems, aeration, iron removal, degassing (of toxic gases), ultraviolet or ozone sterilization and others. Bore hole water is most likely to be of a high quality, however, it must be pumped and its supply is often limited. Fortunately, *Clarias* larvae are fairly tolerant of poor water quality and water drawn from rivers may successfully be used, although the likelihood of the introduction of pathogens is increased, often with disasterous consequences.

Pathogen control

Maximum opportunity for disease prevention is available during the design stage of a new culture facility (Wester 1977). It is obviously preferable to incorporate appropriate measures for disease control in the hatchery design, rather than attempting to add them after the facility has been built and is in operation. It is essential to maintain high standards of hygiene in the hatchery environment. A hatchery should therefore be constructed in a way that facilitates the efficient maintenance of hygiene eg:

- no smoking in the hatchery
- staff who work in the production ponds should not enter the hatchery
- hatchery staff should be issued with overalls and gumboots for exclusive use in the hatchery.

Minimizing stress

It is accepted that stress is a major factor rendering a fish susceptible to disease. Because fish are reared in very artificial environments, hatchery design must be aimed at creating the least stressful rearing conditions.

A major cause of stress is that of handling. For example, physical injury and the disruption of the mucous coat over the skin render a fish particularly susceptible to bacterial and fungal infection. The hatchery

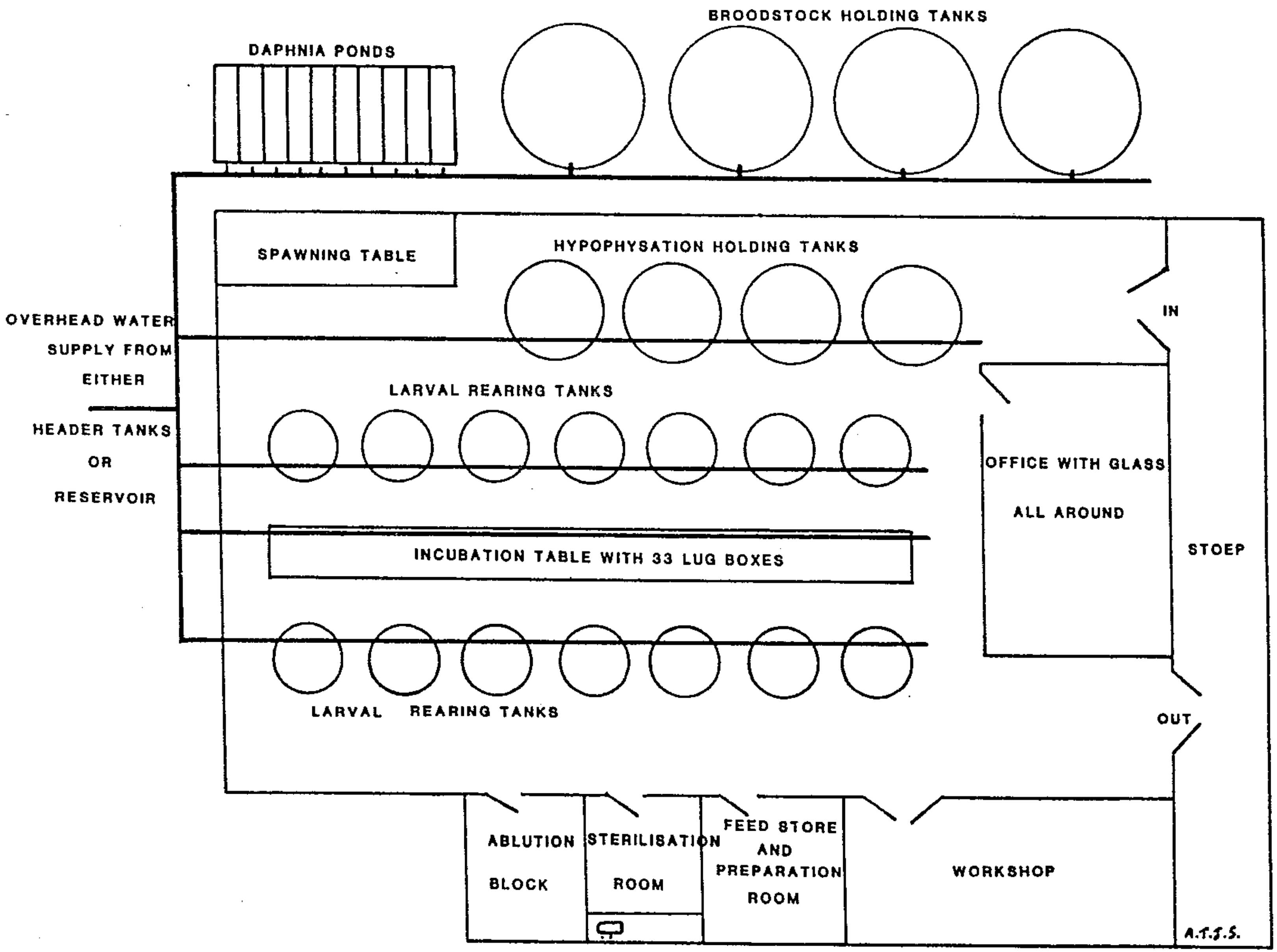

FIGURE 4.1 A basic design for a sharptooth catfish hatchery.

should be designed so that broodstock and larvae are handled as little as possible. Tanks should be laid out so that larvae can swim from the incubation trough into the rearing container. Broodstock containers should be designed so that fish do not have to be chased in order to catch them.

Light is stressful to *Clarias gariepinus* larvae (Britz 1988) and rearing containers should be subjected to a low light intensity or darkness. Light induced stress may also be alleviated by the provision of some form of cover (eg shadecloth netting).

CONCLUSION

Given the fledgling but rapidly developing nature of the sharptooth catfish culture industry in southern Africa, it is appropriate at this stage, to consider the economic implications of intensive larval rearing for the future of catfish culture. Due to the capital and running costs of a hatchery, seed production forms a significant proportion of the costs of a culture operation. One of the major running expense items of a hatchery is wages. The reason for this is because the larval rearing operation demands skilled personnel and is labour intensive. At current prices, it is estimated that the cost of fingerlings will presently form 15 to 25% of production costs if purchased from fingerling producers (W Uys personal communication). On the other hand, if a hatchery is to be constructed, it is estimated that at least a million fingerlings will have to be produced per annum for such a hatchery to be cost effective. A certain economy of scale thus applies with regard to sharptooth catfish production as a whole. While it is cost effective for large-scale farms to invest in a hatchery, employing management and labour, it is probably more economic for the small-scale producer to purchase fingerlings from larger producers for grow-out. It has become clear that successful larval rearing requires careful management, technical competence and experience. This may favour the establishment of specialist seed producers, to supply fingerlings for grow-out. This trend is already evident in the Netherlands where the catfish culture industry has divided itself into specialist fingerling producers and relatively small-scale grow-out operations (Huisman and Richter 1987).

The techniques for the artificial propagation and larval rearing described above are largely the product of scientific research programmes and provide a valuable foundation for the mass rearing of fry. Experience gained at commercial hatcheries in South Africa has obviously been taken into consideration in the preparation of this chapter. In general, however, very little experience exists with respect to the mass rearing of fry on a commercial basis, and the techniques described here will, no doubt, be improved upon as this experience is gained. The recommendations made here should thus be regarded as a set of guiding principles, rather than as definitive techniques, from which fry rearing on a large commercial scale may be developed.

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CHAPTER 5. NUTRITION

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INTRODUCTION

Feeding usually represents the single most expensive production cost in intensive aquaculture (Shang 1981). Therefore the development of dry optimal feeds is considered to be one of the major tasks in aquaculture research (Ghittino 1972; Tiews et al 1979). In South Africa, the relatively low market price for table fish and the high price of feed ingredients require that intensive aquaculture ventures be based on a sound system of efficient feed conversion. From an economical point of view, this would mean the establishment of a system in which money spent on feed is profitably converted into income derived from the sale of fish. It is evident, therefore, that an understanding of the dietary requirements of *Clarias gariepinus* is a prerequisite for its commercial culture. In 1985, commercial feed formulation was considered to be the most important step in developing the culture technology for *C gariepinus* (Hecht 1985). That this view was also shared by Dutch workers is reflected in the number of nutrition related research projects on *C gariepinus* which have since been conducted in the Netherlands (Henken et al 1985, 1986; Machiels and Henken 1985, 1986, 1987; Machiels and van Dam 1987).

Research concerning the nutrition of fishes has a relatively brief history. Before 1950 production diets consisted primarily of fresh or frozen abattoir by-products and raw fish (Nose 1979). Nutrition studies on salmonids escalated in the 1950's and early 1960's (Halver 1953, 1957a,b; Phillips 1956) and the subsequent development of commercial moist feeds (Hublou 1963) and dry feed (Hastings and Dupree 1969; Fowler and Barrows 1971) has pushed intensive fish husbandry toward real industrialization.

In the 1970's a great number of research papers on fish nutrition appeared, reflecting the increasing importance which nutrition and feed technology began to play in the rapidly developing global aquaculture industry. In 1972, two major syntheses on fish nutrition appeared. One was a compilation of review papers edited by Halver (1972) and the other a detailed review by Cowey and Sargent (1972). Most of the investigations still dealt with salmonids, but by then, a sound fundamental knowledge had been established regarding their dietary requirements for energy (Phillips 1972), protein and amino acids (Mertz 1972), vitamins (Halver 1972), and lipids (Lee and Sinnhuber 1972).

As the aquaculture industry developed and diversified in the 1970's, especially with the advent of channel catfish (*Ictalurus punctatus*) culture in the USA, an increasing demand for balanced commercial fish feeds necessitated and increased research effort. It is evident from the Proceedings of the World Symposium on Finfish Nutrition and Fish feed Technology (Halver and Tiews 1979), that a shift in emphasis occurred toward the economics of fish feeding. Feed formulation studies dealt mainly with the substitution of conventional but expensive, protein sources, such as fishmeal, with less expensive ingredients (Higgs et al 1979; Spinelli et al 1979; Tiews et al 1979). Attention was also given to feed manufacturing technology (Csavas et al 1979; Meyers 1979; van Limborgh 1979).

Rapid advances in the field of fish nutrition and fish feed technology in the last decade, have led to a well established applied science. Commercial feed formulation studies have developed beyond the stage where attempts were made to simply substitute expensive ingredients with less costly one. It has now entered the realm of computerized least costing. This technique is now widely applied by commercial fish feed manufacturers.

For a better understanding of applied nutrition in *Clarias gariepinus*, fundamental aspects such as the natural feeding biology, the morphological adaptations of feeding, and the physiological processes involved need to be considered.

The following paragraphs present a brief review of the fundamental aspects of fish nutrition. Following this the specific dietary requirements of *C gariepinus* are reviewed and finally, recommendations are made for feed formulation and feeding practices for the commercial culture of this species.

FUNDAMENTAL ASPECTS OF FISH NUTRITION

The nutrients

Proteins are complex, organic compounds composed of amino acids linked by peptide bonds and form the basic structural units of animal tissue. Animals require dietary amino acids in specific ratios. Usually these are in accordance with the ratios of amino acids of the body proteins which are to be formed. It is evident, therefore, that if the amino acid ratios in the dietary protein are unbalanced, then the apparent utilization of dietary protein would be poor. Consequently the animal would have to ingest more protein in order to satisfy its requirements. A further complication may arise when a diet is deficient in energy, and amino acids are catabolized for their energy. From an economical point of view, it is important that feeds be well balanced in order to realize favourable feed conversion ratios. Protein is the most expensive component in commercial fish feeds and much attention has been given to the optimization of its use in aquaculture (Halver 1980a). Wilson (1985) provides a succinct review of the amino acid and protein requirements of most of the commercially cultured fishes.

Carbohydrates are utilized by omnivorous and herbivorous fishes as an energy source and several cultured fish species have been shown to possess the necessary enzymes to digest significant amounts of starch (Chow and Halver 1980). Amylase is also present in the digestive tract of *C gariepinus* and the species can to a large extent utilize starch as an energy source (Uys and Hecht 1987).

Lipids are a concentrated energy source in fish diets but also provide essential fatty acids. Fish require polyunsaturated fatty acids (PUFA) of the "w3" family (plant and fish oils) (Kanazawa 1985). In practical diets, the level of lipid supplementation is usually restricted by the inability of pelletizing high fat diets and the susceptibility of PUFA's to oxidation (Stickney 1984). Kanazawa (1985) reviewed the latest advances in the understanding of essential fatty acid and lipid requirements of fish.

Vitamins are non-nutritive dietary essentials required in small quantities. They act as catalysts in physiological processes. Dietary vitamin deficiencies lead to poor growth, irregular bone formation, susceptibility to disease and a number of other undesirable effects. The advances in the knowledge of vitamin requirements of fish have constantly been reviewed by Halver (1972, 1979, 1980b) and the latest advances are summarized in Halver (1985).

Although fish can absorb minerals directly from their environment, it has been shown that deficiency symptoms can occur in fish that are fed on diets with a very low mineral content (Lall 1979). In general, little is known of the quantitative mineral requirements of fish. Minerals, in the form of a premix, are usually added to feeds in excess of the demand. This practice is relatively inexpensive. It seems that mineral supplementation is only essential in diets with high levels of plant ingredients. Ingredients such as fish meal, carcass meal and the like are themselves good sources of dietary minerals. Calcium and phosphorous can be supplemented to diets as calcium phosphate (usually about one per cent) and indications are that the trace minerals such as magnesium, iron, cobalt and zinc are required at levels of less than 0,01% of the diet (Lall 1979).

NATURAL FEEDING BIOLOGY OF *CLARIAS GARIEPINUS*

From reports on the natural feeding biology of *C gariepinus* it is evident that it has highly variable feeding habits. Spataru et al (1987) identified more than 50 species of animals and plants from the intestines of one population of *C gariepinus*. Seasonal changes in the diet of *C gariepinus* seem to be correlated to the relative abundance of food items, rather than being an adaptation to nutritional requirements. This opportunism is also reflected in the difference in their diets from one location to another (Bruton 1979). When prey fish are plentiful *C gariepinus* becomes almost entirely piscivorous. On the other hand it can efficiently graze on zooplankton and algae and will also consume higher plants and detritus (see Chapter 1).

The variety of feed habits which have been ascribed to this fish by various authors are seemingly contradictory but they do substantiate the notion that *C gariepinus* is an opportunistic omnivore. Some authors are in agreement, however, that *C gariepinus*, although euryphagic, is predominantly a predator, with fish being the most important prey of adult specimens (Schoonbee 1969; Richter 1976; Bruton 1979) and that it will feed on invertebrates, plants and detritus as an alternative (de Kimpe and Micha 1974).

Its propensity toward a carnivorous feeding habit seems to indicate that *C gariepinus* has a relatively high dietary protein requirement, in the order of 40 to 50% of crude protein on a dry weight basis. Prey fish is probably the most important source of dietary lipids and it is therefore very likely that its digestive system is geared toward utilizing polyunsaturated fatty acids as an energy source. The fact that the animal also feeds on plant material reflects its ability to digest plant proteins and utilize carbohydrates as an energy source. From a commercial culture point of view, euryphagy holds the benefit that a wide variety of feed ingredients of plant and animal origin may be considered in formulating feeds which will satisfy the fish's dietary requirements. The diet of post-larval and early juveniles of *C gariepinus* consists mainly of zooplankton and other invertebrates. This is also the case with most other cultured fishes. In fact the dietary requirements of young *C gariepinus* differ little from those of carp, trout and channel catfish.

FUNCTIONAL MORPHOLOGY OF THE DIGESTIVE SYSTEM OF *CLARIAS GARIEPINUS*

Its gross anatomical adaptations for feeding allow *C gariepinus* to take prey ranging in size from minute zooplanktors to fish half it own length (Bruton 1979). The wide mouth, large gape and circumoral barbels facilitate bottom feeding in turbid water, In addition, the well developed gillrakers allow efficient filtering of surface scum and midwater organisms. The oesophagus is short and dilatable, facilitating the passage of large food items. In the stomach, food is crushed and tumbled by the muscular stomach wall. The intestine is simple, thin walled and relatively short, implying a dependence on protein rich foods. A study of the development of the fine structure of the alimentary tract and associated organs (Uys and Hecht unpublished) revealed that *C gariepinus* has a generalized digestive system which develops relatively fast during its life history. This enables the fish to utilize a wide range of diets efficiently from an early age.

These adaptations and its opportunistic feeding habits are of great benefit to the aquaculturist. Feed can therefore be presented in a variety of ways and still be utilized efficiently (eg floating pellets, large pieces of offal, fine particles, sinking pellets). Pond cultured catfish have been observed to snatch sinking pellets before they reached the substratum, then feed off the substratum and finally surface to filter feed on floating "fines".

DIETARY REQUIREMENTS OF *CLARIAS GARIEPINUS* (APPLIED NUTRITION)

Dietary requirements of larvae

Due to the high densities at which *C gariepinus* larvae are reared, it is essential that a reliable source of high quality larval feed is at hand in the hatchery. Live food organisms such as rotifers, cladocerans (Uys and Hecht 1985; Polling et al 1988) and *Artemia* cysts and nauplii (Hogendoorn 1980; Verreth et al 1987) have been used with success in the experimental mass rearing of *C gariepinus* larvae. However, the collection of live food organisms from ponds is an unreliable and cumbersome exercise, and the cultivation of Artemia is both expensive and time consuming.

In a series of research projects Hecht (1981, 1982), Uys (1984) and Uys and Hecht (1985) investigated the dietary requirements of *C gariepinus* larvae. These efforts culminated in the formulation of an artificial dry feed (Uys and Hecht 1985). Based on subsequent experience (Britz and Hecht 1987; Hecht and Appelbaum 1987), it is recommended that the artificial dry feed by used as a primary food source in the hatchery and that live food be presented to the fish once a day. For practical reasons, the original Uys and Hecht (1985) formulation has been revised. The recommended formulation, manufacturing procedure and application rates of the revised dry feed are given in Table 5.1. Torula yeast can be obtained from health food outlets and some pharmacies. The vitamin premix as given in Table 5.2, can be substituted with capsulated multivitamin mixes which are commonly sold in pharmacies. Laboratory sieves or nylon meshes with appropriate mesh sizes can be used for sieving the particles into the required size ranges. It must be emphasized that once the oil mixture is added to the dry feed it should be used within 24 hours to prevent oxidation. An antioxidant can obviously be used but it is more practical to add the oil to the food on a daily basis.

TABLE 5.1 Recommended formulation of a dry feed for *Clarias gariepinus* larvae and early juveniles

Torula yeast (Candida utilis)	50%
Fish meal	43%
Vitamin Premix*	1%
Cod liver oil	3%
Sunflower oil	3%
	100%

Procedure:
1. Mix yeast and fish meal with water to produce dough.
2. Roll dough out into thin cakes and dry at 45°C in oven.
3. Grind the dry cakes and sieve into particles size ranges 125-200 m and 200-350 m respectively. Store this stock mixture in sealed containers below 5°C.
4. On a daily basis, mix the proportional amount of oil and vitamins with an appropriate amount of stock mixture. Discard what is not used within 24 hours.

Application:
Use fine particles (125-200 m) for first four days and coarse particles (200-350 m) on subsequent days.
Apply at least 20 g per 500 litre container every 2 hours, day and night, and in any case, not less than 40% of body weight per day.

*Vitamin premix as in Table 5.2

TABLE 5.2 Tentative vitamin premix for *Clarias gariepinus* diets, based on levels used in commercial diets for channel catfish (Robinson 1984)

Thiamin	11 g
Riboflavine	13 g
Pyridoxine	11 g
Pantothenic acid	35 g
Nicotinic acid	88 g
Folic acid	2,2 g
B12	0,09g
Choline	550 g
Ascorbic acid	350 g
A (IU)	4400 (IUx1000)
D (IU)	2200 (IUx1000)
E(IU)	55 (IUx1000)
K (IU)	11 (IUx1000)

Note: Make up to 2 kg with a filler such as maize meal. One kilogram of this mixture should be sufficient for one ton of pelletized feed (0,1%) or 500 kg of extrusion processed feed (0,2%).

Dietary requirements of juveniles and subadults

Clarias gariepinus has a relatively high dietary protein requirement. However, it is an efficient converter of food and can utilize a wide range of feeds effectively. This premise is suggested by the data on its natural feeding biology and functional morphology, and is substantiated by results of digestive enzyme assays (Uys and Hecht 1987; Uys et al 1987) and feeding trials (Machiels and Henken 1985; Henken et al 1986; Uys and Hecht unpublished).

The best growth rates and feed conversion efficiencies are achieved with a diet consisting of 38 to 42% crude protein and an energy level of 12 kJ g^{-1} calculated digestible energy (Table 5.3). These two levels are the most important dietary aspects pertaining to commercial feed formulation since they largely determine the cost of the feed.

Since no data is available on the digestibility of feeds for *C gariepinus*, digestible energy (DE) values as determined for channel catfish, *Ictalurus punctatus* (Table 5.4) had to be used for the calculation of DE in the experimental feeds. DE values are not interchangeable between species (Jobling 1983), but until such values are established for *C gariepinus*, those that apply to channel catfish are most likely the best, since it appears that there is very little difference in the overall dietary requirements between these two species.

Optimum lipid content of the diet was found to be 10 to 11 %, but this will vary according to the energy provided by carbohydrates in the diet. A lipid content of eight to 10% is recommended. However, this must be adjusted in order to attain the energy requirement of 12 kJ g^{-1} calculated DE.

No conclusive results are available yet on the dietary vitamin and mineral requirements of *C gariepinus*. Until more research in this field can is conducted, it is recommended that vitamin supplements be applied in accordance with the levels used in commercial channel catfish feeds (Robinson 1984) (Table 5.2). It is also recommended that mineral supplements be added only to such diets which contain less than 20% ingredients of animal origin (eg fish meal or carcass meal).

From and age of six weeks the dietary requirements of *C gariepinus* do not seem to change (Uys and Hecht unpublished), except that the optimum feed ration decreases with age. As the fish grow older their relative food consumption rates decrease from approximately 10% of body weight per day (four weeks old) to two per cent of body weight per day (10 weeks and older). Similarly, growth rates decrease from 14 to two per cent of body weight per day and feed conversion ratios increase from 0,7 to 1,3. Hogendoorn et al (1983) proposed a size and temperature related model for the estimation of daily ration for *C gariepinus*. Based on their data, as well as those of Uys and Hecht (unpublished) a size and temperature related feeding schedule can be proposed (Table 5.5). It must be emphasized that this feeding schedule should serve as a guideline only, and that daily ration should be adjusted in accordance with measured growth rates in order to ensure a favourable feed conversion ratio.

Formulation of least cost diets

Programmed least cost feed formulation is a common technique in the animal feed industry. Most programs are aimed at finding the cheapest way of combining a given set of ingredients with known nutritional composition while at the same time satisfying the nutritional requirements of the animal concerned. To compute a least cost diet the requirements of the animal are used as constraint values. Upper and lower bounds should therefore be attached to the inclusion levels of the respective ingredients. Least costing can, and should be taken one step further by least costing the fish produced and not just the feed itself. This is facilitated by, a sensitivity analysis of the nutrients (eg protein). For instance if the sensitivity of protein in a particular formulation is R20, it means that if the protein restriction (requirement) is reduced by one per cent, the new formulation would be R20 cheaper. Assuming that it is known to what extent the growth of the fish will be affected by this reduction in protein content, one can now weigh the advantage of cost saving on the diet against the reduction in expected growth rate and feed conversion efficiency. An example of such a computerized least costing exercise is presented in Tables 5.6 and 5.7. These are printouts of the input and output data of a computer program which is used to formulate commercial catfish feed.

Table 5.8 shows the results of a series of least cost diets which were used in a feeding trial with *C gariepinus* (Uys and Hecht unpublished). From Table 5.8 it is evident that at current ingredient prices, the feed cost to produce one kilogram (live weight) of catfish is highly economical (58 to 71c kg^{-1}). It also demonstrates how unconventional ingredients (eg tomato waste) can make a large contribution to the economic efficiency of catfish feeds. All the diets in Table 8 comply with the constraints, 40% protein, more than eight per cent lipid, 12kJ g^{-1} DE, but different ingredients were used to make up the various

TABLE 5.3 Recommended proximal composition for a *Clarias gariepinus* production feed

Dietary requirements (contraints in linear programming terms)			
Crude protein			38-40%
Total lipid			>8%
Digestible energy			12 kJ/g
Calcium			1,5%
Phosphorus			0,5%
Bounds on ingredients:	**lower**	**upper**	**reason**
Fishmeal	10%		amino acids
Molasses powder	8%	12%	binder
Oil supplement		8%	pelletability
Vitamin premix**	0,1%		as for *I punctatus*

*For DE values of ingredients, use those determined for channel catfish (Table 5.4).
**Vitamin premix as in Table 5.2.

TABLE 5.4 Digestible energy values for channel catfish (*Ictalurus punctatus)* as given by Lovell (1984)

Ingredient	DE (kJ/g)
Wheat	10,7
Raw corn (maize)	4,6
Cotton oil cake	10,7
Soy oil cake	10,8
Fish meal	16,3
Meat ad bone meal (carcass meal)	14,5
Alfalfa meal (lucern)	2,8
Fish oil	36,9

Note: Until digestibility determinations are conducted for *C gariepinus*, the values in this table can be used tentatively for the calculation of DE for *C gariepinus* diets.

test diets. The results provide a simulation of a real situation where the availability of the ingredients fluctuate. In all cases the resulting growth rates, feed conversion ratios and costs to produce on kilogram of fish were very similar. This serves to illustrate the flexibility which is allowed by least cost philosophy.

TABLE 5.5 Recommended feeding schedule for *Clarias gariepinus* under intensive earthern pond culture conditions

	Mean individual weight of fish					
	1-10g	10-25g	25-50g	50-100g	100-300g	300-800g
TEMP °C						
20	5,0	3,0	2,0	1,5	1,0	
22	7,0	4,5	3,0	2,5	2,0	
24	8,0	6,0	4,0	3,0	2,5	
26	9,0	6,5	5,0	3,5	3,0	
28*	10,0	7,0	5,5	4,0	3,5	2,0
30	10,0	7,0	5,0	3,5	3,0	
32	10,0	7,0	5,0	3,5	3,0	

*Only the values in the 28°C range were determined by the author. The rest of the values are estimations based on a model proposed, and data presented by Hogendoorn et al (1983).

Note: Values are daily rations expressed as a percentage of body weight per day. Split ration into two portions (morning and evening) for temperatures above 20°C. For temperatures of 20°C and below, apply ration as single portion in evening. This schedule should serve as a guideline only. Weekly samples of fish should be taken in order to determine mean weights. Daily rations should be adjusted in accordance with realized weight gain to ensure favourable FCR.

CONCLUSION

A sufficiently sound working knowledge of the nutritional requirements of *C gariepinus* now exists for application in commercial culture. Purely from a feed cost point of view the intensive culture of *C gariepinus* is economically feasible. All animal husbandry ventures are, of course, at the mercy of feed prices on the one hand and market demand for the product on the other. An adverse shift in either of these factors might render the venture uneconomical overnight. Favourable growth rates and feed conversion ratios, despite the high dietary protein requirement of the fish, substantiate the notion that *C gariepinus* is a prime candidate for the development of a warm water aquaculture industry in southern Africa.

Further research into least cost formulations as well as fundamental nutritional issues should be continued for as long as commercial *C gariepinus* culture is a reality. Of immediate importance in this field, are digestible energy determinations of conventional as well as unconventional feed ingredients. Dietary mineral and vitamin requirements of *C gariepinus* need to be further researched. Although valuable work on the effect of temperature on the nutritional requirements of *C gariepinus* has been published by Hogendoorn et al (1983) and Henken et al (1986), this avenue of research needs to be further investigated in

TABLE 5.6 Example of input for computerized least cost formulation of a 40% protein diet for *Clarias gariepinus*

Ingredient	Cost	Bounds Lower	Bounds Upper	Prot %	Fat %	DE kJ/g	Ca %	P %	Meth %	Lys %
				Data input form				catmix2.DT		
Maize	305	0	100	9	4	4,6	,22	,201	0	0
Cotton O	500	0	10	44	4	10,7	,38	1	0	0
Wheat	320	0	100	15	1,5	10,7	,86	,225	0	0
Soy O/C	640	0	20	44	,9	10,8	,65	,7	0	0
Sun O/C	500	0	100	38	1	7	,65	,81	0	0
Fishmeal	1050	12	100	64	10	16,32	2,1	1,85	0	0
PBPM	650	0	8	70	21,4	14,27	,696	,59	0	0
Carcass	665	0	30	55	12	14,52	3,5	,83	0	0
Dicalp	200	0	1	0	0	0	28	16	0	0
Lucern	300	0	100	15,5	2	2,8	,2	,2	0	0
Ac Oil	700	0	10	1	99	36,94	,1	,1	0	0
Tomato	80	0	15	26	14,37	7	,2	,2	0	0
Molass	247	8	100	4	2	12	,1	,1	0	0
Vit/Min	9000	,1	100	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0	0	0
Minimum requirements:				40	11	12	1,5	,5	0	0

TABLE 5.7 Example of output from computerized least cost formulation of a 40% protein diet for *Clarias gariepinus*

Ratios to mix as follows:

Ingredient	Quant %	Cost of formulation = 517,2176	
Maize	0	Prot = 40 %	
Cotton O	10	Fat = 10,99992 %	
Wheat	11,78605	DE = 12 kg/g	
Soy O/C	0	Ca = 1,47505 %	
Sun O/C	0	P = ,6788057 %	
Fishmeal	12		
PBPM	8		
Carcass	27,89973	Sensitivity analysis	
Dicalp	0	Nutrient	Unit cost
Lucern	6,311436	Prot	7,248015
Ac Oil	,8963919	Fat	4,064153
Tomato	15	DE	3,247606
Molass	8	Ca	0
Vit/Min	,1	P	0
Total	= 99,99361		

TABLE 5.8 Examples of least cost diets for *Clarias gariepinus* with resulting feed conversion rations (FCR) and cost efficiencies

Diet No	1	2	3	4	5	6	7	8	9	Control
Maize%	-	4,6	15,0	30,0	-	10,5	-	-	-	18,0
Wheat%	-	31,8	15,0	-	30,0	-	14,0	-	-	18,0
Cotton O/C%	-	-	-	-	-	25,0	-	-	-	-
Soy O/C%	10,0	-	-	-	-	10,0	10,0	-	-	-
Fishmeal%	24,7	16,0	10,0	10,0	10,0	20,0	10,0	10,0	-	43,5
Poultry bpm%	10,0	10,0	-	10,0	10,0	9,0	10,0	26,0	35,2	-
Carcass meal%	10,5	27,6	50,2	39,5	31,4	-	22,7	-	-	10,0
Lucern meal%	30,0	-	-	-	-	-	-	-	-	-
Tomato waste%	-	-	-	-	9,7	8,0	20,0	50,1	50,0	-
Fish acid oil%	6,8	-	-	2,5	0,9	7,5	3,3	5,9	6,8	2,5
Molasses powder%	8,0	10,0	9,8	8,0	8,0	10,0	10,0	8,0	8,0	8,0
Crude protein%	38,0	38,0	38,0	38,0	38,0	38,0	38,0	38,0	38,0	38,0
Total lipid%	13,5	8,0	8,1	11,7	9,8	14,2	12,5	19,8	21,6	9,0
DE (kJ/g)*	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0
Price/ton (R)	655,0	586,0	580,0	569,0	543,0	603,0	531,0	415,0	376,0	722,0
FCR	1,05	1,19	1,16	1,25	1,19	1,13	1,12	1,46	1,54	0,98
Cost/kg fish**	0,69	0,70	0,67	0,71	0,65	0,68	0,59	0,61	0,58	0,71

* Calculated on the basis of DE values for channel catfish (Lovell 1984).
** Feed cost to rear 1 kg of fish.

order to provide feeding schedules and diet formulation for winter months as well as for colder geographical regions. The potential of hitherto unacceptable feed ingredients (from an aesthetic or health point of view), such as abattoir wastes, diseased carcasses and activated sludge from domestic sewage should be investigated. *Clarias gariepinus* could well be used to convert waste products such as these into a marketable product. Also, the legal restrictions on the use of unregistered feed ingredients should be urgently reconsidered.

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CHAPTER 6. PRODUCTION AND GROW-OUT

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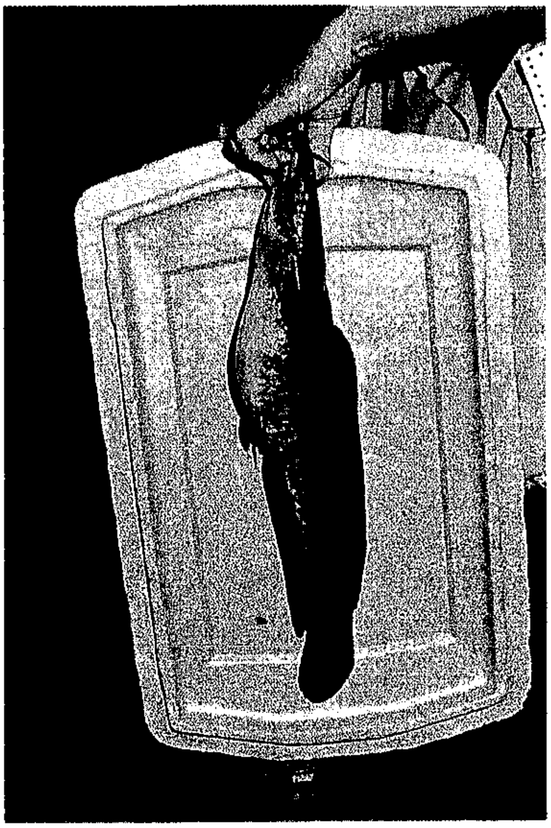
INTRODUCTION

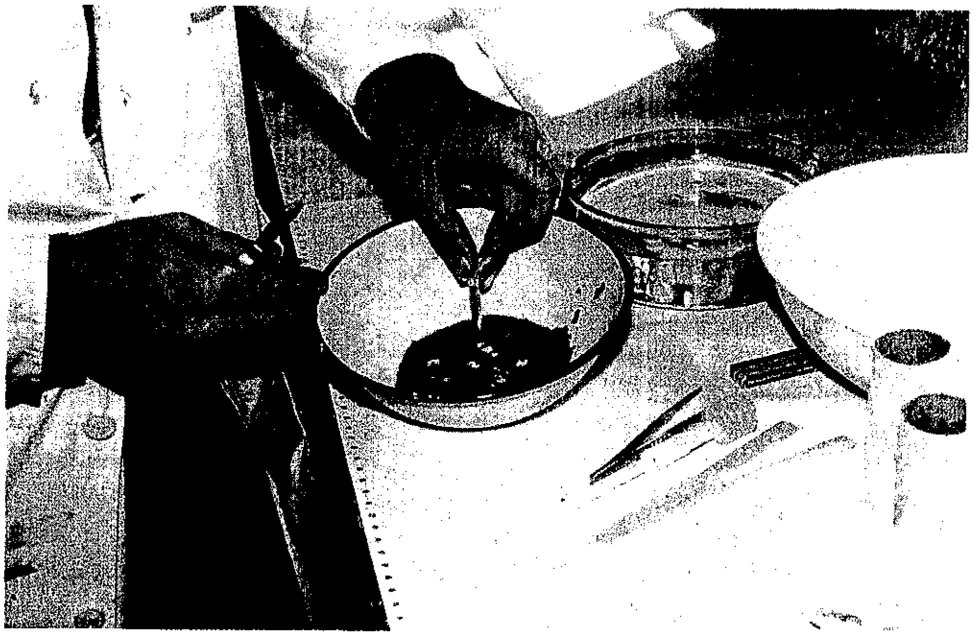
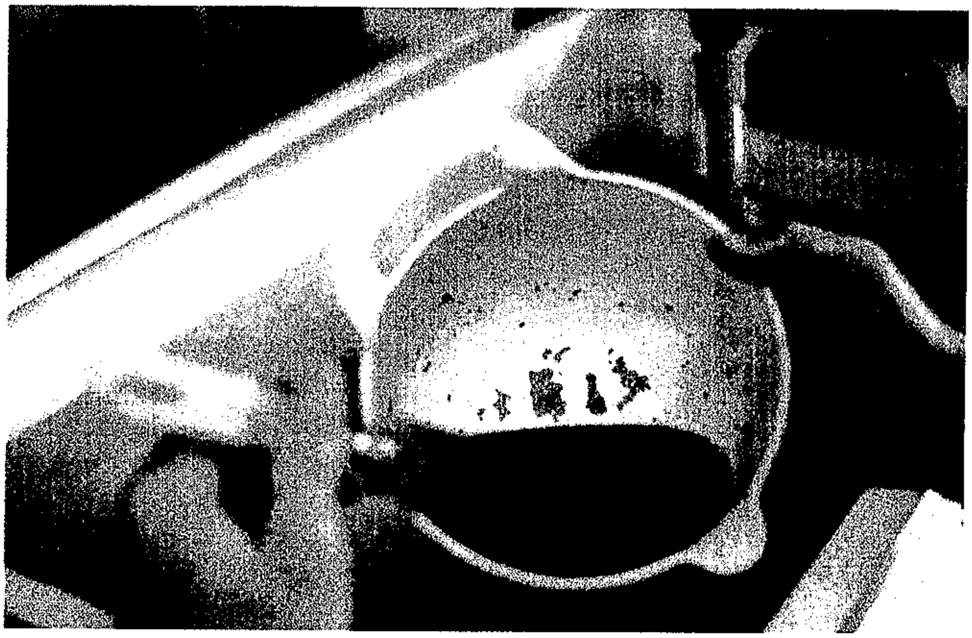
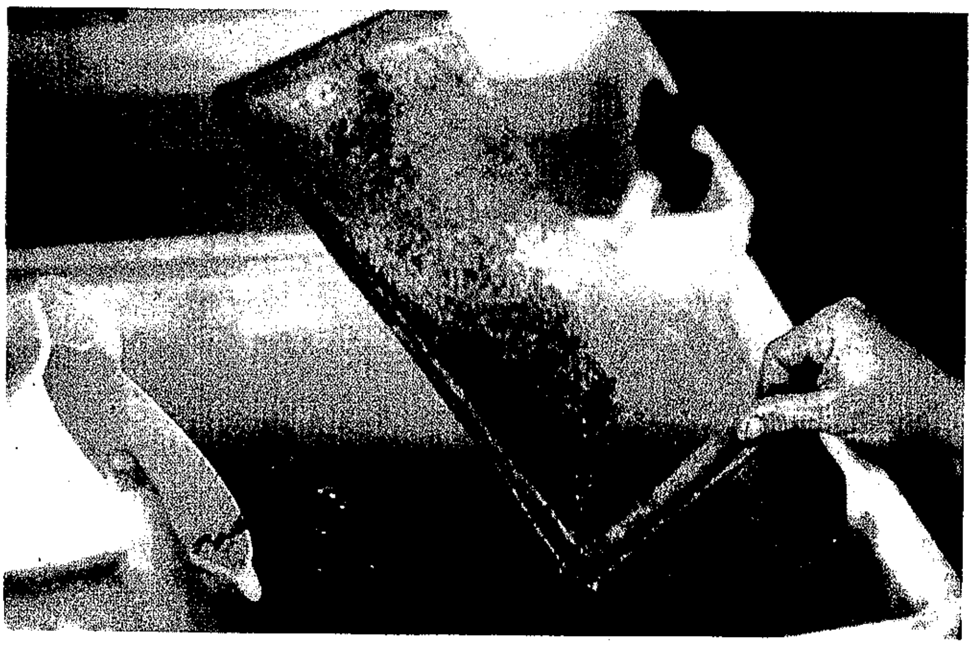
The development of fish culture has resulted in a variety of culture systems which can be classified on the basis of the nature of the enclosure and the production intensity. Earthern ponds are the most common enclosures but cages, pens, raceways and closed recirculating systems are also used. Production intensities vary from extensive culture, in which the natural pond productivity fulfills the nutritional requirements of the cultured fish, to intensive culture in which practically all the nutrients have to be provided in the form of formulated feeds.

Most warm water fish culture systems in southern Africa are somewhere on the continuum between extensive and highly intensive culture. Water supply and quality, space, feed cost, land and construction costs and the biology of the cultured species are all factors which should be considered when deciding on the level of intensity. Given the favourable climatic conditions in several regions in southern Africa (see Chapter 3), and based on experience (van der Waal 1972; de Kimpe and Micha 1974; Richter 1976; Bok and Jongbloed 1984; Hecht 1985), it seems that semi-intensive to intensive earthern pond culture is the best choice for this species. In Thailand *Clarias batrachus*, a close relative of *C gariepinus* are traditionally grown in small stagnant earthern ponds of 100 to 3 000 m^2 (Areerat 1987) and in the USA the bulk of channel catfish (*Ictalurus punctatus)* production takes place in earthern ponds (Tucker 1985).

Bovendeur et al (1987) propose a water recirculating, intensive culture system for *C gariepinus*. Such systems are currently used for the commercial production of this species in the Netherlands (Huisman and Richter 1987). Closed, recirculating systems allows accurate manipulation of water quality, but are expensive to build and maintain. However, as mentioned above they do provide a solution to water quality management in otherwise unsuitable culture environments, where water is scarce and ambient temperatures are unfavourable. Such closed systems require a high degree of technological sophistication and are not recommended for commercial application in Africa where the approach should rather be to seek an appropriate site where temperature, water quality and quantity are appropriate and sufficient.

In the remainder of this chapter, only semi-intensive to intensive earthern pond culture will be considered with the assumption that ample water and space is available and that favourable climatic conditions prevail.



OBJECTIVES OF PRODUCTION

From an economical point of view the objective is to convert feed into fish as quickly and as profitably as possible. This can only be achieved if the underlying biological processes are understood. For example, the limitations that govern the rate at which *Clarias gariepinus* can convert feed, should be known, in order not to apply feed at a greater rate than the particular system can manage. In order to manage the culture system to its full economical potential the primary factors which need to be considered include feed conversion ratio (FCR), specific growth rate (SGR), standing crop and temperature. In the following sections, locally developed production techniques and their limitations are discussed.

NURSERY POND MANAGEMENT

Nursery ponds

In a nursery pond, hatchery reared fry 16 to 25 mm TL are reared to 30 to 50 mm TL "fingerlings". It is of the utmost importance that a nursery pond be free of predators and disease vectors before stocking. The best way to achieve this is to drain and sun-bake the pond a few days before stocking is intended. Nursery ponds should be fenced in and the inlets screened to prevent clawed toads (*Xenopus* laevis) from entering the pond once it is filled. The pond outlet should also be screened to prevent the juveniles from escaping. The pond should be filled only one or two days prior to stocking. This practice does not allow populations of natural food organisms to develop in time for the arrival of the juveniles. However, this disadvantage is offset by the advantage of having a predator-free nursery pond. In newly built ponds, it is advisable to manure the substratum before each inundation. Eventually, a layer of sludge accumulates on the substratum, and populations of natural food organisms tend to develop quickly after each filling. Moreover, considering the high stocking densities which are recommended (see the following section), natural pond production and live food only play a small role in the total nutrition of the fry.

Stocking

Successful techniques have been developed for the mass rearing of larvae in a hatchery (Hecht 1981, 1982; Uys and Hecht 1985; Britz and Hecht 1987) (see also Chapter 4). It is recommended that fry only be stocked into nursery ponds once they are at least 10 days old and have reached an average size of 25 to 30 mm TL. Stocking densities of up to 2 000 fry per square metre of pond area (20 million ha^{-1}) are recommended. Lower stocking densities may by preferred if nursery pond space is not limited. Viveen et al (1986), recommended a stocking density of only 65 fry per square metre in nursery ponds. However, this implies that about 10 nursery ponds of 100 m^2 each are required to stock 65 000 fry and harvest 20 000 fingerlings at a 30% survival rate. In our experience, only one such nursery pond is required to stock 200 000 fry and harvest up to 50 000 fingerlings at a 40% survival rate. In Thailand, *C batrachus* nursery ponds are stocked at a density of 350 to 400 fry per square metre (Areerat 1987), however, grow-out takes place in the same ponds and there is no reduction in density.

Feeding

The fry should be fed at least three time per day, at a ration of 25% of body weight per day. Due to the high protein and energy requirements of the fry and since feed cost is of little consequence during this stage, pure fish meal can be used as feed.

The fry should be sampled frequently and inspected for signs of malnutrition or disease. At these high stocking densities malnutrition can manifest itself and disease can spread rapidly.

During this stage, sibling cannibalism is probably the greatest cause of mortality. It can best be prevented by adequate feeding (Hecht and Appelbaum 1988). These authors have also shown that the rate of cannibalism increases with density and the provision of cover was found to reduce the rate of cannibalism.

Water supply

At the above stocking densities a water exchange rate of 0,5 litres per minute per square metre of pond area was found to be more than adequate for nursery ponds. At low stocking and feeding levels, a slow flow rate to compensate for seepage and evaporation is sufficient. It is advisable that a reserve water supply capable of delivering 1 000 litres per minute be available for pond filling, or flushing when water quality becomes unfavourable in the ponds.

Size sorting

Three weeks after stocking, the pond should be drained and the juveniles (now approaching fingerling size) should be size sorted into three classes. Size sorting is best achieved using a series of screens with hole diameters of six, 10 and 16 mm respectively or a barred parallelogram sorter.

Several weight classes are usually encountered in any one pond (eg Figure 6.1). It is advisable to cull the group of smallest individuals, particularly if that size class is 20% or less of the total population. The rationale is that the cost of replacing culled fry is far less than trying to rear fish that perform poorly. The largest individuals within the population usually make up a very small proportion (less than one per cent of the population) and it is advisable to rear these separately as broodstock. If size sorting is not undertaken, cannibalism can result in nursery pond stock losses of up to 99%.

After the first size sorting, the juveniles are restocked into nursery ponds, each size class to a separate pond. After another week, the fish attain "fingerling" size (30 to 40 mm TL). The size sorting exercise should be repeated before the fingerlings are finally stocked into grow-out ponds.

Harvesting of fry or fingerlings

Harvesting of nursery ponds is best achieved by netting the pond with a fine shade cloth or gauze net while the pond is being drained. Once the pond has receded to 30% of full capacity, the screen at the outlet is removed and the remaining fry or fingerlings are collected in a fine net placed below the outlet.

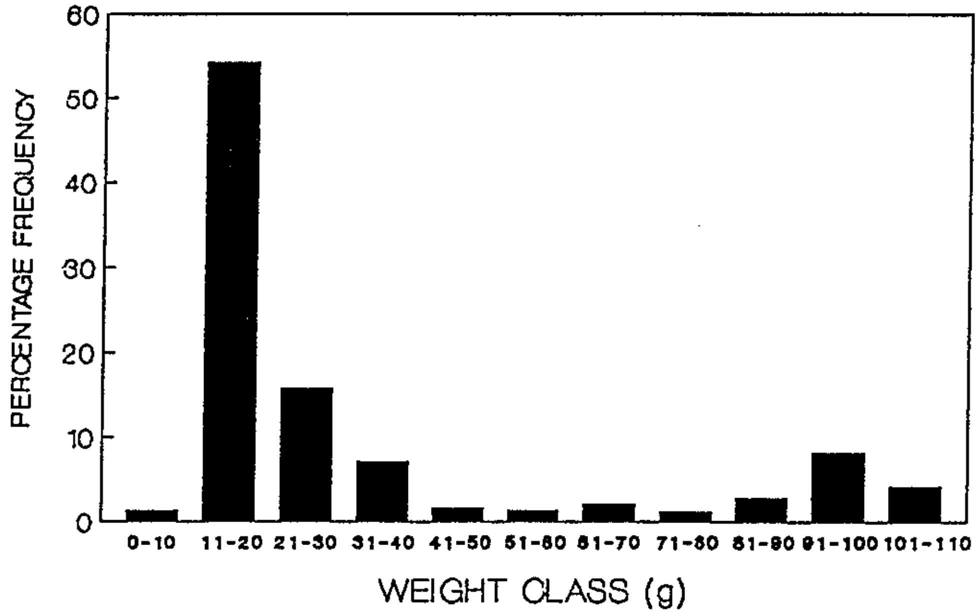


FIGURE 6.1 Example of the per cent weight frequency distribution of *Clarias gariepinus* in an earthern pond.

Note: The above results are based on the following experiment. Approximately 5 000 one-day old larvae were stocked into a 2 000 litre circular plastic pool. They were fed in excess twice a day on catfish larval feed. Some live food organisms, mostely cladocerans, entered the pool with the water supply. After 50 days the pool was drained and only 425 survivors were found. Since no dead fish were encountered the losses were ascribed to cannibalism. The importance of size sorting can therefore not be overemphasized.

Juvenile catfish up to a length of about 35 mm TL are fragile, and should be handled with extreme care. Survival rates from hatchery fry to fingerlings ready for stocking are, on average, fairly poor. However, this is largely due to the culling of "runts" during size sorting. Survival rates are of the order of 10 to 50% at best. Inefficient feeding practices placés the fish under stress which can result in monogenean trematode and/or *Trichodina* infections, which can decimate the entire stock.

GROW-OUT POND MANAGEMENT

Stocking

Before stocking a grow-out pond, it should also be drained and allowed to bake dry. Viveen et al (1986) recommend that fingerlings be stocked at a density of 100 000 ha^{-1} (10 fish per square metre). In Thailand, *Clarias batrachus* fingerlings are stocked at densities of 0,5 to one million per hectare (20 to 30 mm TL) and later thinned out to 300 000 to 600 000 ha^{-1} (50 to 70 mm), depending on the water exchange rate (Areerat 1987). Based on our present experience, it is recommended that fingerlings be stocked at a maximum density of 100 000 ha^{-1}. The population has to be thinned out at regular interval in order to maintain the population at a maximum standing biomass of not more than 40 tons ha^{-1}, at a constant water exchange rate of the pond once every four days. This implies that some fish will have to be placed out to other ponds or marketed as they grow. Production of *C batrachus* in Thailand (Areerat 1987) and *C gariepinus* in Zambia (Hecht 1985) indicate that a standing crop of 65 to 100 tons ha^{-1} is attainable. It is, however, advisable not to exceed 40 tons ha^{-1} until current research on economically optimum stocking densities is completed.

Short-term management

If the fingerlings are of a uniform size when stocked, cannibalism is effectively eliminated. As an additional precaution, the pond should be drained every two months in order to remove and keep in seclusion fish that are more than twice the size of the population mean. Furthermore, this is a good management practice, because it allows stock records to be brought up to date. Catfish do not seem to be much affected by such frequent handling as long as precautions are taken against prolonged exposure to dry or hot conditions. Pond draining should be restricted to cloudy, cool days if possible.

One of the most important management practices is to maintain accurate records of stocks, growth rates and feed conversion ratios (FCR). Samples should be taken from ponds at approximately weekly intervals. This is best achieved with a cast net or small seine net. A random sample of at least 50 fish should be collected of which the mean weight should be determined accurately in order to keep a log for each pond (Table 6.1). When the pond is drained every second month (or whenever doubt exists as to the accuracy of the estimated population number) a sample of a hundred fish or more should be weighed to determine a more accurate mean, after which the whole population must be weighed to calculate the total number of fish.

The maintenance of accurate records allows the manager to ensure that favourable feed conversion ratios are realized and maintained and that the fish are in good condition. The feed conversion ratio (calculated using the formula FCR = Weight of feed consumed/increase in wet weight of fish) provides a direct index of the economic performance of a pond. When using dry, balanced rations a FCR of 1,2 or better should be achieved. If this is not the case, the feeding schedule should be adjusted accordingly. In conjunction with the recommended feeding schedule presented in Table 5.5, the following factors should be taken into account when calculating a feed ration for the ensuing period: poor condition, slow and differential growth and a favourable FCR are indicative of underfeeding, whereas polluted water and a poor FCR are factors indicative of overfeeding.

Long-term management

An overall pond management strategy should be worked out in advance in order to make maximum use of pond space while taking into consideration

TABLE 6.1 Example of short term record sheet for pond culture of *Clarias gariepinus*

Pond No 6 Pond area 1000 m² Date stocked 10/2/87

Date	Average temp (°C)	Sample size	Mean weight (g)	No days since previous sample	Weight increase per fish (g)	Growth rate (g/day)	Specific growth rate SGR (% body weight per day)	Estimated or deter-mined no of fish	Calculated or deter-mined mass (kg)	Increase in mass (kg)	Amount of feed fed	FCR	Recommended ration for next period	Feed/ pond/ day (kg)	Comments
D	C	n	x	t	x1-x0	(x1-x0)/t	{log(x1)-log(x0)}/t x100	N	M= (N x m)/ 1000	dM	Ff	Ff/	(% body weight per day)		
10/2/87	29	100	124,2	n/a	n/a	n/a	n/a	8000 (det)	993,6	n/a	n/a	n/a	3,5%	34,8	Stock ex pond 4
22/2/87	30	22	167,2	12	43,0	3,6	2,5	8000 (est)	1337,6	344,0	416	1,21	3,5%	46,8	All's well
30/2/87	27	27	191,8	8	24,6	3,1	1,7	8000 (est)	1534,4	196,8	375	1,91	2,5%	38,4	Fed too much!
10/3/87	27	25	236,5	10	44,7	4,5	2,1	8000 (est)	1892,0	357,6	383	1,07	2,8%	53,0	Good FCR
etc....	..	...	.....	..	....	...	...	....	......	.....	...	....	....	....	

the limitations imposed by other factors such as, market demands, labour, transport, processing capacity and cash flow. It would be a grave error to stock all the ponds to maximum capacity simultaneously. Consider, for instance, a production facility which is aimed at producing 100 tons of sharptooth catfish per year. If all the ponds are stocked simultaneously, and assuming that all the fish reach marketable size within a month of each other, enough pond space to facilitate a standing crop of almost 100 tons is required. Feed would have to be applied at a rate of about two tons of feed per day. In addition, for a period of one month labour, marketing and transport resources of a 100 tons (4,5 tons per week-day) capacity will be required. On the other hand, if stocking dates are staggered, some ponds might lie idle for a while, but only in the first year. Furthermore, instead of attempting to market 100 tons of fish within a one-month period, marketing should gradually increase to about eight tons per month, year round (ie 360 kg per working day). A maximum stock of only about 30 tons will have to be accommodated at any given time. Using a staggered stocking and harvesting strategy, full production potential cannot be achieved in the first year. However, this does allow time for the development of markets and for management staff to acquaint themselves with a new venture.

Since fingerling production is essentially restricted to the summer months (October to May) and since growth is temperature dependent, long-term management strategies have to take the seasonal nature of production into consideration. In order to maintain a constant supply of marketable fish, summer production will have to compensate for the slow growth rates in winter. One could consider keeping a reserve of harvested fish in deep frozen storage, but it is most likely more economical to keep them in reserve ponds until they need to be marketed.

Hogendoorn et al (1983) developed a useful model for predicting the growth rate of *C gariepinus* as influenced by temperature and body weight. The model is based on laboratory results and our experience shows that pond grown catfish perform somewhat better than the estimates produced by the model. A limitation of the model is that it only pertains to fish of up to 200 g in weight. Nevertheless, since it is (at this stage) the only basis upon which to estimate productivity, a table of estimated growth rates based on the model of Hogendoorn et al (1983) is provided (Table 6.2). Much more research is needed before detailed appraisals of growth rates under different conditions can be made. As a rule of thumb, however, *Clarias gariepinus* can be expected to grow to a marketable size of one kilogram over a period inclusive of one full summer in areas with a subtropical climate. This means that a crop of fingerlings stocked in October should be ready for harvesting by May in the following year. Should they be stocked later in summer, they would have to be kept over winter and will most likely only be ready for harvesting 12 months after the stocking date. In temperate areas, such as the Transvaal highveld, catfish might therefore have to be reared over a period inclusive of two summer seasons.

Based on these assumptions, it appears advisable to stock a substantial number of fingerlings in summer as soon as they become available. The rest should be stocked at monthly intervals until the end of the spawning season.

The long-term planning exercise in Table 6.3, illustrates how 25 ponds (0,15 ha in extent) should be managed in order to achieve a constant monthly harvest of about nine tons per month. The example given in Table 6.3 could probably be improved upon, since the capacity of each pond is underutilized while the fish are small. For example "fingerlings" which are eventually destined for four ponds, could initially be stocked into one pond and only divided up later, thereby making three ponds available for other purposes. Therefore, with careful planning, fewer ponds can produce more fish in the same period.

An alternative strategy would be to stock all the ponds in October, in the hope of producing 100 tons of fish within 10 months. The production cost per kilogram of fish would be much lower, but it is doubtful whether any form of marketing could accommodate such a cyclic production of fish.

It must be emphasized that expectancies created by such paper exercises are seldom realized. Floods, management errors, competition in the market place and plain bad luck are all factors which can jeopardize the prediction of Table 6.3.

TABLE 6.2 Estimated growth rates (% of body weight per day) for *Clarias gariepinus* from one to 200 g between 20 and 35°C (from Hogendoorn et al 1983)

Temp	Body weight (g)					
(°C)	1	5	25	50	10 0	200
20	3,1	2,6	1,5	1,1	0,6	
21	4,2	3,6	2,3	1,7	1	0,4
22	5,3	4,6	3	2,3	1,4	0,6
23	6,3	5,6	3,8	2,9	1,9	0,9
24	7,2	6,5	4,4	3,4	2,2	1,1
25	8,0	7,3	5	3,8	2,6	1,2
26	8,7	7,9	5,4	4,2	2,8	1,4
27	9,2	8,3	5,7	4,4	2,9	1,4
28	9,6	8,5	5,8	4,4	2,9	1,4
29	9,7	8,6	5,7	4,3	2,8	1,3
30	9,7	8,5	5,6	4,2	2,7	1,2
31	9,6	8,5	5,2	3,9	2,4	1,1
32	9,3	7,7	4,8	3,5	2,2	
33	8,8	7,2	4,3	3,1		
34	8,2	6,5				
35	7,5	5,8				

TABLE 6.3 Example of long term planning for production of 100 tons of catfish per year in 25 earthen ponds of 0.15 ha each

Pond No	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	St	---	---	---	---	---	---	1	2				St	---	---	---	---	---	---	---	---	---	3	3			St
2	St	---	---	---	---	---	---	---	1	2			St	---	---	---	---	---	---	---	---	---	3	3			St
3	St	---	---	---	---	---	---	---	---	2	2		St	---	---	---	---	---	---	---	---	---	3	3			St
4	St	---	---	---	---	---	---	---	---	---	2	3	St	---	---	---	---	---	---	---	---	---	---	---	5	St	---
5	St	---	---	---	---	---	---	---	---	---	2	3	St	---	---	---	---	---	---	---	---	---	---	---	5	St	---
6		St	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---	---	---	---	---
7		St	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---	---	---	---	---
8		St	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---	---	---	---	---
9			St	---	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---	---	---
10			St	---	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---	---	---
11			St	---	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---	---	---
12				St	---	---	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---
13				St	---	---	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---
14				St	---	---	---	---	---	---	---	---	---	---	---	---	3	3	St	---	---	---	---	---	---	---	---
15					St	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3					St	---	---
16					St	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3					St	---	---
18					St	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3					St	---	---
19						St	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3			St	---	---
20						St	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3			St	---	---
22						St	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3				St	---
23														St	---	---	---	---	---	---	---	---	---	---	---	3	3
24														St	---	---	---	---	---	---	---	---	---	---	---	3	3
25														St	---	---	---	---	---	---	---	---	---	---	---	3	3

Marketable fish (t)								1	3	4	6	6	9	9	9	9	9	9	9	9	9	9	9	9	10	9	9
Feed purchases (t)	10			10		10		10			10	10	15	15	15	15	15	15	15	10			10	10	15	15	15
Fingerlings (x1000)	40	24	24	24	24	24							40	24	24		24		24						40	24	24
CASH FLOW PROJECTION: (x R1000)																											
Income								2	6	8	12	12	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Fixed costs	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Variable costs	10	3	3	8	3	8		6			6	6	13	12	12	9	12	9	12	6			6	6	13	11	11
Total expenses	15	8	8	13	8	13	5	11	5	5	11	11	19	18	18	15	18	15	18	12	6	6	12	12	19	17	17
Surplus/shortage	-15	-8	-8	-13	-8	-13	-5	-9	1	3	1	1	-1	0	0	3	0	3	0	6	12	12	6	6	-1	1	1
Balance	-15	-23	-31	-44	-52	-65	-70	-79	-78	-75	-74	-73	-74	-74	-74	-71	-71	-68	-68	-62	-50	-38	-32	-26	-27	-26	-25

Notes: St indicates when a pond is stocked.
The broken lines --- indicate that a pond is occupied.
The values at the end of the broken lines indicate the likely harvest in tons.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

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CHAPTER 7. PROCESSING OF *CLARIAS GARIEPINUS* AND PRODUCT PRESENTATION

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INTRODUCTION

Lee (1973) and Smith and de Beer (see Chapter 8) state that marketing is a final and important part of fish farming. It is the link between the producer and the market. A market for the fish should be secured before a fish farm is established. Proper processing may be one of the most important steps ensuring the financial feasibility of a sharptooth catfish farm. Furthermore the type of product desired will integrally influence the design and operation of the fish farm and processing facility. Lee (1973) states that processing is sometimes referred to as dressing, but processing is actually more than this. When fish are dressed, the head, the viscera and skin are simply removed. Processing includes other activities, such as packaging and storing, and is undertaken to provide a product that is attractive and appetizing.

PROCEDURES

Processing entails a series of procedures which can be summarized as:

- transporting the fish from the ponds to the processing plant. This must be done quickly and efficiently;
- freshing out - this is accomplished by placing the fish in tanks with a high water exchange rate with aeration for two to three days;
- stunning by electrical means;
- deheading - either by means of a band saw or chopper;
- eviscerating - the entire length of the belly is slit and the viscera are removed; and
- washing.

Depending on the demand of the market the fish are now ready to be size sorted and prepared according to the demand of the market. Should the market demand skinned fish or fillets (see later) one of the following procedures can be followed:

Manual skinnning is done by hanging the fish by their heads on large hooks. The dorsal and pectoral fins are snipped off and the skin is cut through all round the fish just behind the operculum. Pliers are used to grasp the edges of the cut skin, which is stripped off in a tailward direction.

Mechanical skinning requires the removal of the head and viscera before skinning. One method involves pushing the fish over a skinner much as a joiner is used in a woodwork shop. This machine must be adjusted in such a way that a minimum of flesh is removed with the skin. A disadvantage of this method is the concomitant removal of the thin white membrane which lies between the skin and the flesh. This membrane protects the flesh and keeps it moist. When removed, the quality of the fish declines more rapidly.

The skin may also be removed by a combination of rubber and stainless steel rollers. The steel roller has a multitude of tiny "teeth" which grip the skin and peel it from the flesh, leaving the thin protective membrane on the flesh intact.

Chemicals are presently being tested for the skinning of sharptooth catfish.

FORMS OF SHARPTOOTH CATFISH PREPARATION

The different forms of preparation are largely based on the demands of the consumer. The size of the fish may also dictate the form of processing.

- Whole - this is the fish in its natural form, also referred to as "round" or "in the round".
- Drawn - involves the removal of the viscera but leaving the head and skin on the fish.
- Dressed - the viscera and skin as well as the head and the fins are removed. A fish weighing approximately 450 to 800 g is well suited for this form of processing.
- Steaks - steaks are obtained by cutting cross-sections of 20 to 25 mm thick from dressed fish. A cross-section of the backbone is included with each steak. Fish weighing more than one kilogram are suitable for this form of processing.
- Fillets - this cut contains no bones and is made by cutting a side section away from the backbone from a fish of which the skin has been removed. This form of preparation yields a low dressing percentage (ca 43%). Fillets may be made from large or small fish (see Figure 7.1).
- Other processed products - smoked, prepared in various other forms or minced products, fish sticks, crumbed or with batter.
- Conventional and microwave-ready products.

Dressing percentage and processing loss may have a significant effect on the economy of catfish production. *Clarias gariepinus* has dressed yield of 55 and 60%.

If a dressing percentage of only 55% is obtained, 45% of the fish is a potential loss to the producer. This loss may often be higher in the case where the fish is filleted (fillets only yield 43% dressed weight), necessitating the innovative utilization of these fractions. In certain situations, the backbone is left intact on one side of the fish when it is filleted, thus reducing the loss. A more feasible approach may, however, be to process the offcuts into a saleable product, such as petfood. If this can be done in an economical way, the profitability of the enterprise could be increased substantially.

THE SMOKING OF SHARPTOOTH CATFISH

This is achieved by impregnating the flesh of the fish with the empryreumatic products contained in the smoke. This permits the preparation of delicate specialities. Certain woods like conifer wood, must not be used. During the smoking process the temperature must be regulated and the rate of circulation controlled. Smoking can be either hot or cold. The details of preparation and the actual process are described by Desrosier (1963).

Distinction should be made between artisanal and industrial smoking installations. The first can simply be a chimney provided with hood, a hearth and twigs used for smoking. Industrial curing includes galleries with a special smoking installation and a system which forces the smoke to circulate (Huet 1979).

THE SALTING OF SHARPTOOTH CATFISH

Salting involves the partial dehydration of the fish by osmosis with sodium chloride. Dressed fish are salted as soon as possible after being caught, especially if the temperature is high. There are several ways in which fish can be salted:

- Dry salting. This involves the stacking of alternate layers of fish and salt.

- Brining. Several salt solutions can be used depending on the requirements. A light brine with less than 16% salt, an average brine with 16 to 20% salt or a strong brine, with more than 20% salt.

- Cold salting. This is achieved by spreading salt and crushed ice on the fish (10 to 12 kg of salt for 100 kg of ice).

When using a light brine or when cold salting Huet (1979) suggests that the fish should be kept in a cold room (two to three degrees Centigrade); for average brine the temperature can rise to 16°C and if a strong brine is used the fish can be kept at ambient temperature.

EFFECT OF PROCESSING ON QUALITY

The effect of processing on the end product is extremely important. Every effort should be made for regular quality control checks. For example refrigeration at between 0 and six degrees Centigrade slows the process of degradation, although after a certain time the flesh may become soft and flabby and lose its flavour (Desrosier 1963).

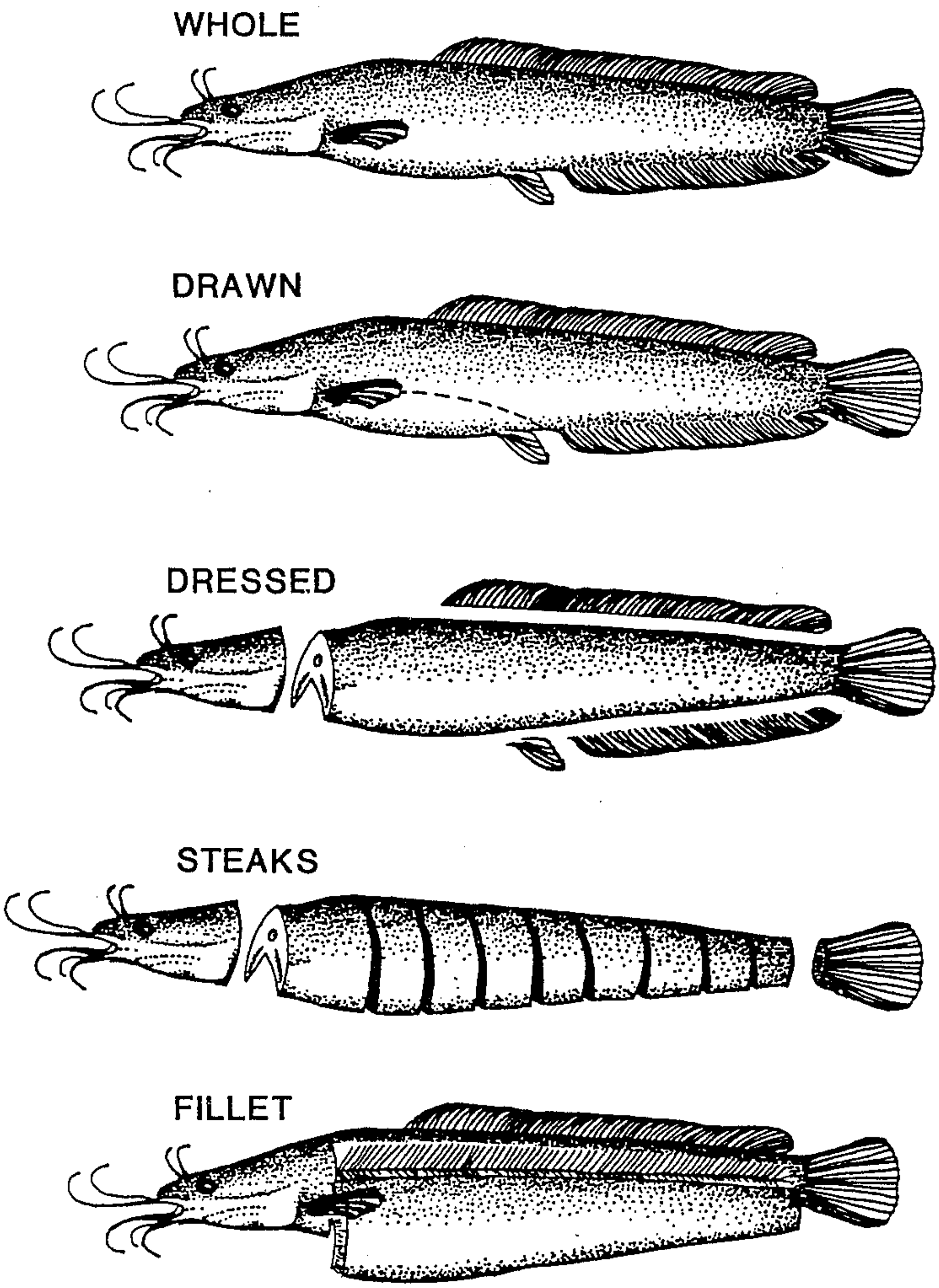

FIGURE 7.1 Different forms of preparing sharptooth catfish.

Deep freezing of fish at -10°C or less will permit preservation for a long time. Only the freshest fish in good condition should be deep frozen. Before freezing the fish should be eviscerated and washed.

Jul (1984) indicates that industry, trade and consumers have for a long time been interested in possible quality changes in foods due to freezing and subsequent thawing. Several authors assume that any change due to freezing and thawing would result in a reduction in quality. This is not necessarily correct. Several changes during food preservation may not be noted by the consumer and there are other cases where measurable quality change may actually be perceived as an improvement. Similarly the assumption that freezing will result in a loss in nutritional value is not justified. This subject does, however, need more thorough investigation.

Frozen fish has to a large extent replaced salted and dried fish which has led to an increase in fish consumption throughout Africa. Because of these changes the freezing of foods has had a profound impact on the nutritional status (intake, consumption) of society.

It is often stated that products must be frozen at a very high freezing rate "quick frozen". The published information, however, suggests, that the rate of freezing has practically no influence on the quality of the frozen product. For example no differences were found in the taste of cod fish when frozen either at 0,15 cm per hour or at five centimetres per hour. Normally a freezing rate of not less than 0,5 cm per hour is recommended. Figure 7.2 illustrates the effect of freezing rate on fish.

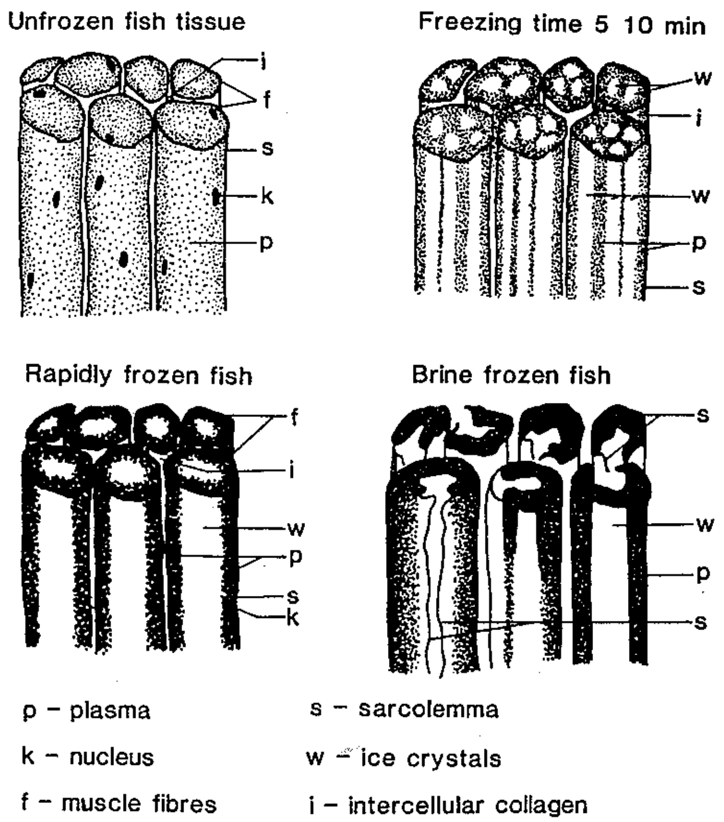

FIGURE 7.2 Effect of freezing on fish muscle.

The quality of a frozen food may be greatly enhanced by improving packaging eg vacuum packaging. Of considerable importance to the industry and the frozen food trade, is to be able to determine what the quality of the product is likely to be at the time when it has moved through the normal frozen food chain and is ultimately consumed. Information of this kind would enable manufacturers to date label their products.

STRUCTURE AND COMPOSITION OF FISH FLESH

A knowledge of the structure and composition of the fish is essential in order to facilitate the correct approach to and implementation of the right procedures during processing.

Aitken and Connell (1979) indicate that all fish muscle is typical striated muscle, although in each case the cells are arranged in special configurations. In most fishes the ends of the typically short, striated cells are inserted into sheets of connective tissue, arranged in a complicated pattern which, on heating, break down and give rise to the characteristic flaky appearance. Two main types of muscle exist, red and white. The former is found laterally along the body in discrete strips or blocks between the skin and the backbone. Different species of fish contain different proportions of red and white muscle, the latter generally dominate.

The lipids of fish are amongst the most unsaturated of animal-muscle lipids. Whether as phospholipids or triglycerides, they contain high proportions of polyunsaturated fatty acids, which in most fish are very susceptible to oxidation by atmospheric oxygen during handling and processing. In some species the presence of natural antioxidants retards this tendency. Whether such anti-oxidants occur in sharptooth catfish flesh is not known. The immediate products of oxidation are hydroperoxides which readily break down to a series of carbonyls, several of which have rancid odours and flavours.

Fish contains the normal types of muscle proteins, though the proportion of connective-tissue proteins is lower than in meat, being only three to five per cent of the total protein in many species. This is one of the reasons why fish is much more tender than meat. To the food technologist the special feature of the main fish muscle proteins, including enzymes, is their instability in comparison to their meat counterparts. Thus fish myosins, either when isolated or intact, denature much more rapidly than beef or chicken myosin.

QUALITY CONTROL IN PROCESSING

Irrespective of the degree of processing a quality product should be the ultimate objective of processing. Fish, as most foods, can be likened to delicate products such as perfume, where the valuable essences are easily destroyed by improper handling or processing. Thorner and Manning (1983) list the following as the prime factors responsible for significant quality changes:

- spoilage due to microbiological, biochemical, physical, or chemical factors;

- adverse or incompatible water conditions;
- poor sanitation and ineffective warehousing;
- improper and incorrect precooking and post cooking methods;
- incorrect temperatures;
- incorrect timing;
- poor machine maintenance programme;
- poor packaging.

Any of these factors, either singly or in combination, will contribute to poor quality and effect changes that will be evident in the food's flavour, texture, appearance and consistency.

SANITATION DURING FISH PROCESSING

Relevant points to be considered in an effective sanitation programme are the following:

- Design and construction of the facility. The primary purpose of any structure should be to protect the process and products contained therein. In South Africa the laws governing the design and construction of abattoirs are strict. It is essential that the sharptooth catfish farmer who intends to undertake processing by himself acquaint himself with the relevant conditions governing the erection and operation of an abattoir.

- Processing equipment. This is a very complex topic which relates to general aspects of food machinery design, such as materials used for fabrication, etc. Suffice it to say that this is a very important issue to be considered when setting up a new processing unit.

- Water removal, cleaning and sanitizing.

Sharptooth catfish heads and skeletons can be minced in an industrial mincer and successfully fed back to fish in production ponds. Viscera have to be buried. Abattoir cleaning and sanitation methods are prescribed by the relevant departments of health. The catfish farmer needs to acquaint himself with these regulations. Table 7.1 summarizes the advantages and disadvantages of several sanitizing agents.

Personal hygiene of abattoir workers is imperative. Regulations governing personal hygiene, clothing etc are in existence and should be obtained from the relevant health authorities.

CONCLUSION

A tremendous opportunity exists for the processing of sharptooth catfish, particularly in view of a market which is at present very receptive to new products. It is, however, essential that a quality product be presented in an attractive and professional manner with a reasonable shelf life. Due to the fact that consumers are at the moment just being made aware of sharptooth catfish it is essential that the product is of an outstanding quality. Also there is a definitive need for research into product development.

TABLE 7.1 Advantages and disadvantages of various sanitizers

Compounds	Advantages	Disadvantages
Hypochlorites	Effective against a broad spectrum of micro-organisms. Inexpensive. Easy to use.	Corrosive. May discolour product. May oxidize lipids. Affected by organic Affected by organic matter.
Quats	Noncorrosive. Nonirritating. No flavouring/odour.	Not effective against gram negative bacteria. Film formation. May select for *Pseudomonas* species
Iodophor	Noncorrosive. Easy to use. Nonirritating. Effective against a broad spectrum of microorganisms.	Flavour/odour. Form purple compound with starch. Moderately expensive.

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CHAPTER 8. MANAGING THE MARKETING OF *CLARIAS GARIEPINUS* IN SOUTHERN AFRICA

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INTRODUCTION

The essence of a successful marketing drive is based upon producing the "right" product. In defining this product it is essential for the industry to firstly determine the needs and demands of the target market and secondly, to present a product which satisfies these demands more effectively and efficiently than its competitors (Kotler 1980). Due to the infant status of *Clarias gariepinus* marketing some theoretical principles are outlined below to guide prospective entrepreneurs. A summary of the present marketing of sharptooth catfish is also provided.

MARKETING

To develop an appropriate marketing system, a systematic analysis of the environment within which the organization operates must be undertaken. A marketing system consists of the organization and a set of interacting institutions as well as forces that affect the ability of the organization to serve its markets (Kotler 1980). In its simplest form it consists of a single organization serving a single market with no intermediaries, suppliers or other parties (Figure 8.1). In reality, however, the marketing system is much more complex and consists of the organizational environment, the task environment, the public environment, the competitive environment and the macro-environment.

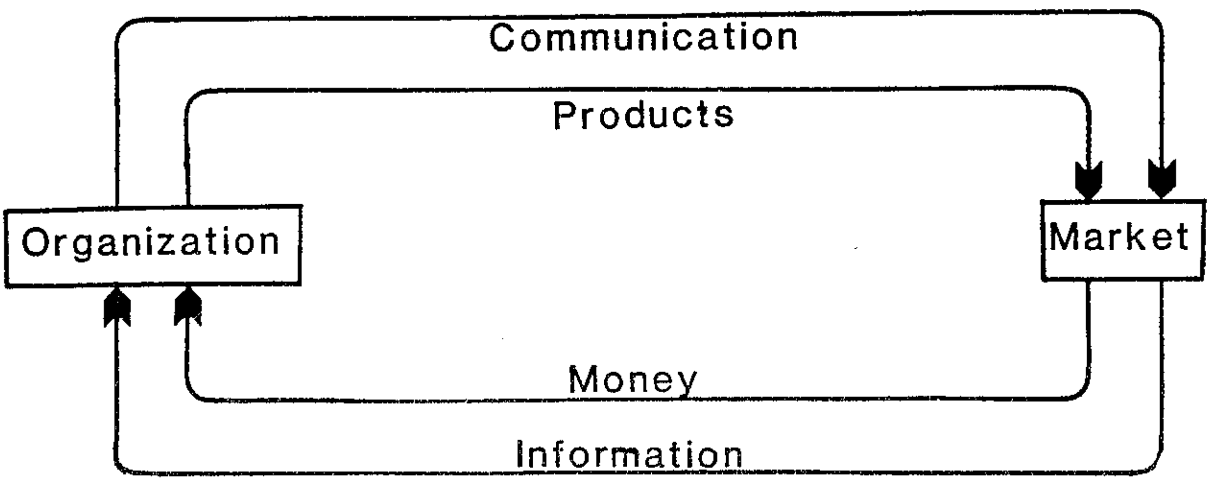

FIGURE 8.1 A simple marketing system.

While each of these components are of importance in an effective system the organizational and task environments are of specific importance as they can be manipulated by management. Cognizance must, however, be taken of the fact that there are a variety of environmental factors beyond the control of any organization that affect the attainment of marketing objectives. Christopher et al (1980) draws attention to the vigorous competition in domestic and international markets. Internally the state of the economy in terms of inflation, changes in income levels, recession and foreign exchange fluctuations affect the level of consumption and the standard of living. The legal environment (Chapter 13) is also complicated and restrictive. In addition to the above the evolution of retail, wholesale, and other distribution networks can take place at such a rate that it is often impossible for the marketers to follow in the short term. All the above variables need to be taken into consideration during the planning phase.

THE ORGANIZATIONAL ENVIRONMENT

The organization itself must have a number of characteristics which will determine its ability to perform in the marketplace. Primarily this includes the efficiency of the individual farming enterprise and the supply of high quality fresh fish to the processors.

THE TASK ENVIRONMENT

The organization operates in a task environment that consists of those basic institutions that cooperate to create marketing value (Kotler 1980). It consists of the producer, the suppliers, the marketing intermediaries and the market. These four together constitute a total marketing system, the interaction of which is necessary to satisfy a particular set of customer needs.

In a new venture such as the sharptooth catfish industry in southern Africa it is of paramount importance to establish a nucleus of reliable suppliers to satisfy the following needs:

- the supply of high quality fingerlings to the industry;
- the supply of high quality feeds to the producers;
- the supply of high quality fish in various forms to the processing units; and
- the supply of drugs, hardware, nets etc to meet the specific demands of the industry.

More than one reliable supplier should be found in order to reduce the risk factor.

Marketing intermediaries assist the company in promoting, selling and distributing its product to the final buyers. These include middlemen, physical distribution firms, marketing agents and financial intermediaries. Figure 8.2 shows the task-marketing system of an organization.

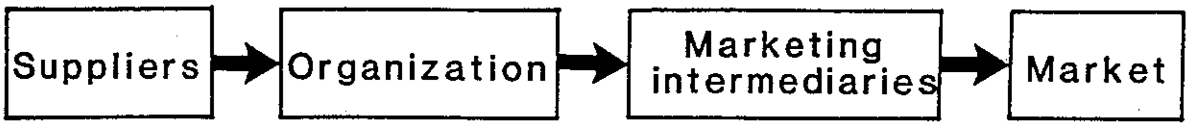

FIGURE 8.2 The task-marketing system of an organization.

The company must weigh the cost of these intermediaries against their sales performance, reliability and cooperativeness. When the company finds existing intermediaries to be inadequate or unavailable, it may be forced to develop its own routes to the market by means of direct marketing (Livingstone 1981). For example, the trout producers in South Africa have found it expedient to create their own marketing structures. This approach may also be the most appropriate for catfish fingerling producers as well as the producers of market size fish.

The market is the final and most important component of the company's task environment. The market is by no means a single entity. A company may sell to several markets, each with its own requirements. We may distinguish between industrial markets which buy for the purpose of processing and resale and the consumer market buying for the sole purpose of consumption.

In developing a market it is essential to study consumer needs and desires. In addition, it is important to develop specific concepts which are aimed at satisfying the needs of the consumer. Also, product features need to be designed and packaging and brand names have to be developed in order to make the consumer want to buy the product. The product has to be priced correctly in order to ensure a reasonable return on investment. Effective marketing communication has to be created to inform the public about the availability of the product. Last but not least, consumer satisfaction has to be monitored in order to be in a position to revise existing marketing strategies based on the results of such surveys.

Well defined plans are extremely important for a company in a new industry, such as the catfish industry, in order for it to penetrate existing markets effectively.

In the effort to penetrate a market the volume of sales must be increased by way of an aggressive marketing plan which may entail the following:

- stimulating current consumers to increase their rate of purchasing;
- attracting the competitors' customers by offering products of higher quality, more attractive prices and wider distribution;
- attracting nonusers by exposing them to the product, either through promotion drives or publicity.

Furthermore, in evaluating the sales potential of a product it is essential to establish:

- who would buy the product?
- how much the customer would be prepared to pay?
- what are the optimal features of the product?
- how many customers would buy?
- where are these customers located?
- who would be the competition?

A thorough consideration of these questions, and the answers to them, sets the stage for a systematic analysis of the market, which would be a prerequisite for a valid target market selection for catfish.

However, in order to make the marketing of *Clarias gariepinus* successful the following are also necessary:

- a consistent supply of fish which meets specific quality standards;
- accessibility to processing facilities and processing know-how; and
- effective distribution channels to deliver the products on a reliable basis.

The marketing opportunities which show promise must be analysed in depth in order to establish how to enter into that specific market. Each market is a composition of various consumer groups having specific needs which might be more diverse than that which the company can serve in a superior fashion. This situation can be addressed by dividing the market into segments that differ in their requirements, buying habits or other critical characteristics.

A producer could therefore supply either a specific product to a specific market segment, or decide to go for product specialization thus supplying a full line of products to all market segments. On the other hand the producer may also decide to specialize in a specific market or alternatively specializing on a selective basis or giving full coverage to the market.

Apart from the needs and desires of customers which influences their purchasing decision, their decisions are to a great extent based on the perception of the product and the interpretation of information supplied about it. If this assumption is correct it can be concluded that the present and future success of any organization is determined by the immediate perception it creates (Peters and Austin 1985). To a large extent this is based on the organizations ability to communicate information about the product.

Once a state of awareness is created, perceptions begin to develop. The addition of further information which can come only via some form of communication will either reinforce a perception or shift it (Webster 1987). Moreover, the basis of success is the identification of the customer followed by the efficient communication of the sales message.

In the identification of the customer and thus the market, it is absolutely essential that the company knows what value the customers want and how their needs are changing. A total commitment to satisfy the customer should be the most important management goal of the sharptooth catfish industry. In fact Peters and Waterman (1982) showed that top companies usually have a close relationship with their customers.

THE COMPETITIVE ENVIRONMENT

An organization rarely stands alone in its effort to serve a given market. Inevitably it operates within a competitive environment. Kotler (1980) stated that these competitors have to be identified, monitored and out-manoeuvered to gain and maintain the loyalty of the market. The state of competition in an industry depends on five basic competitive forces, which are shown in Figure 8.3. The collective strength of these forces largely determine the ultimate profit potential of the industry.

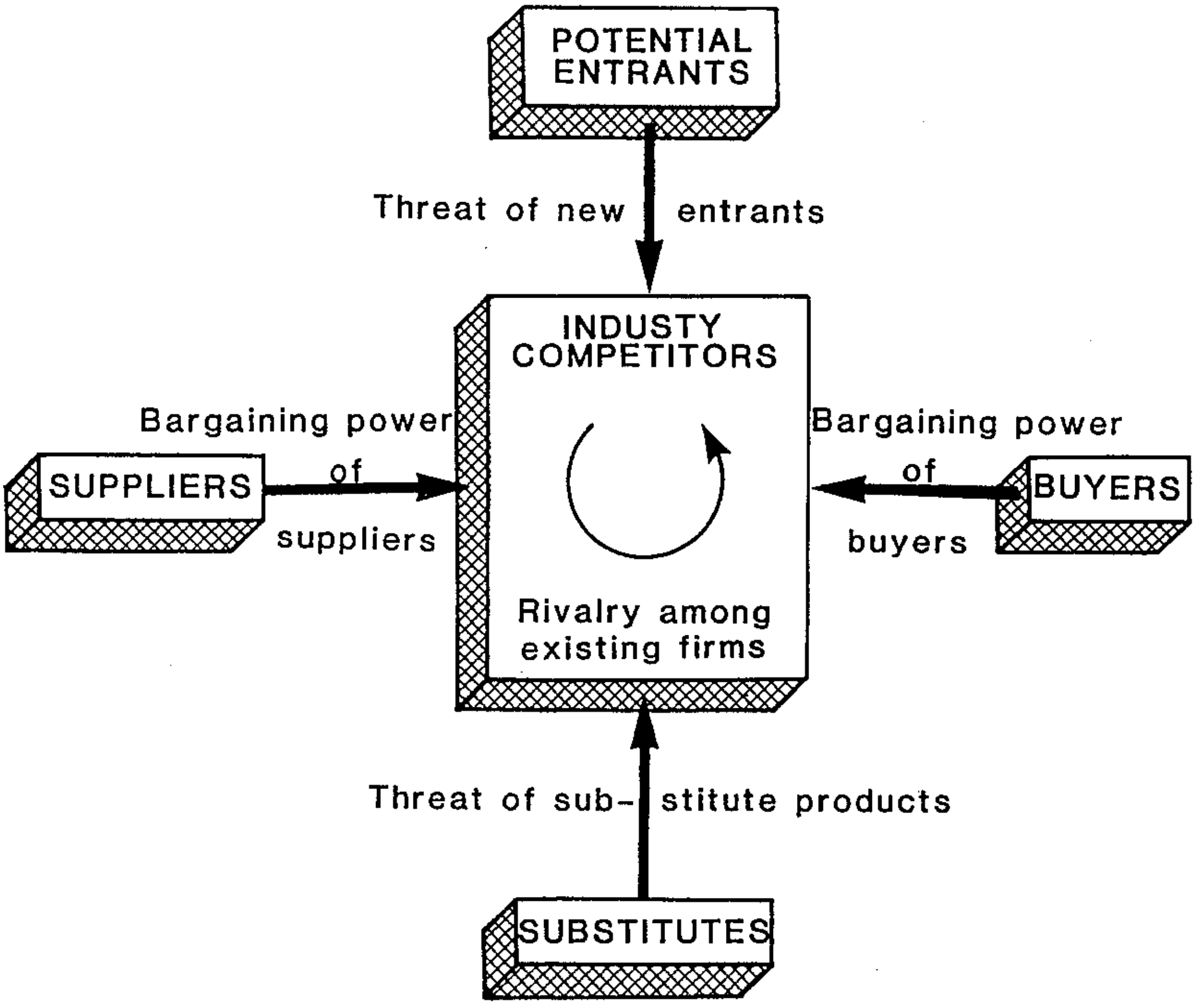

FIGURE 8.3 Forces driving industry competition.

The goal of a competitive strategy is to find a position in the industry where the company can best defend itself against these forces or can influence them in its favour. For example, producers may find it easier to supply sharptooth catfish to the luxury processed product market (smoked and vacuum packed fillets), than to fresh fish markets which are, due to the efficient sea fishing industry, extremely competitive.

From a marketing point of view the fledgling *Clarias gariepinus* industry is faced with two choices. It can either fight for the customers in an existing market by producing a more desirable and better product or it can develop and market a product which is not currently available. In the latter case the producer can thus gain instant leadership. However, before this decision is made, it has to be established:

- whether it will be feasible to produce a specific and special product;
- whether it be economically feasible to produce the product; and
- whether there are sufficient numbers of interested buyers.

In the case of the sharptooth catfish industry there is a great demand in those areas of the country where the fish is a traditional item on the "menu". This enables the producer to adopt a different marketing strategy than a producer in an area where the product is either unknown or has a negative connotation. This perception can, however, be changed with a dynamic marketing drive (cf the American channel catfish industry), but this takes time.

Further important factors affecting the decision on the target markets and the competitive position are:

- how will the producer enter a specific market?
- when would be the most appropriate time of entry?

Entry may be obtained by acquisition, internal development or collaboration. In the case of a new industry like the sharptooth catfish industry, collaboration may be the best approach in order to exploit the new opportunity. The cooperative marketing effort of the South African trout producers is a good example. A major advantage is that risk is shared and therefore reduced for each of the participating producers or companies. It is further possible for each company to contribute specific skills and resources, the lack of which might make it impossible for any individual company to go it alone.

THE PUBLIC ENVIRONMENT

The marketing effort of the industry as a whole or of individual producers can also be influenced by factors related to the public environment, which may, however, if correctly understood be of benefit to the industry. The opposite could, however, also be true. The most important public environment factors are: financial institutions, the media, government departments and statutory bodies.

Financial institutions who take an interest in aquaculture largely determine whether sufficient capital can be obtained in order to initiate and run the operation prior to its becoming self sufficient. These include the commercial banks, the Landbank and the Development Bank of Southern Africa.

Producers are acutely sensitive to the role played by the media in affecting their capacity to achieve their marketing objectives. A concerted effort must be made by all sectors involved in the aquaculture industry, such as producers, intermediaries, wholesalers, retailers etc, to ensure favourable publicity through the media. It is therefore important to offer the press interesting news and informational material.

Aquaculturists should always conduct their farming practices in a responsible way so as to support the image of a wholesome product. Due to the novelty of aquaculture in South Africa it has, up to now, been relatively easy to obtain television and other media coverage. Once the catfish industry has become established this will be more difficult and expensive. Every effort should therefore be made at the moment to use media coverage to the best advantage for the development of the sharptooth catfish industry throughout the subcontinent.

Because the production and marketing of the fish may be hampered by legal restrictions it is important to understand fully the numerous and relevant Acts, laws and by-laws (Chapter 13) laid down by Parliament, central and provincial government departments and other statutory bodies. Liaison with the relevant bodies must therefore be maintained by means of formal representation. Lobbying is thus essential in the arena of the legislative market and must, for the common interest of the industry, be supported by all parties. An important development in this regard is the recent establishment of the Sharptooth Catfish Grower's Association.

THE MARKETING SYSTEM AND PLAN

Once the target market has been chosen and competitors have been identified a market system can be developed. This consists of:

- a marketing organization which will handle sales, conduct market research, promotion, customer services and market planning.

- an information system responsible for enquiries and orders, forecasting of market trends and sales potential, survey of buyers and dealers and analysing sales.

The success of the marketing system will largely be determined by the thoroughness of short-, medium- and long-term planning. The marketing plan should be a written document that spells out the goals, strategies and tactics that will be used. The major elements of the plan are shown in Figure 8.4. It is also of vital importance to establish an equitable marketing expenditure level. This is accomplished by the determination of a marketing budget-to-sales ratio.

The total marketing budget then has to be allocated to the various marketing mix elements. Marketing mix is a key concept in modern marketing theory and consists of set of controllable variables, the levels of which can influence the target market (Figure 8.5). Considering the importance of marketing mix with respect to the producers marketing drive the decisions pertaining to these elements warrant additional scrutiny.

Product decisions

Brown (1987) stated that each product consumes a certain share of marketing costs and in doing so returns to the company a contribution or operating profit. Christopher et al (1980) indicated that products make profits for the company by effectively providing customers with the benefits they seek within carefully controlled cost and revenue parameters. In effective marketing the organization's resources are thus matched with the needs of the customer.

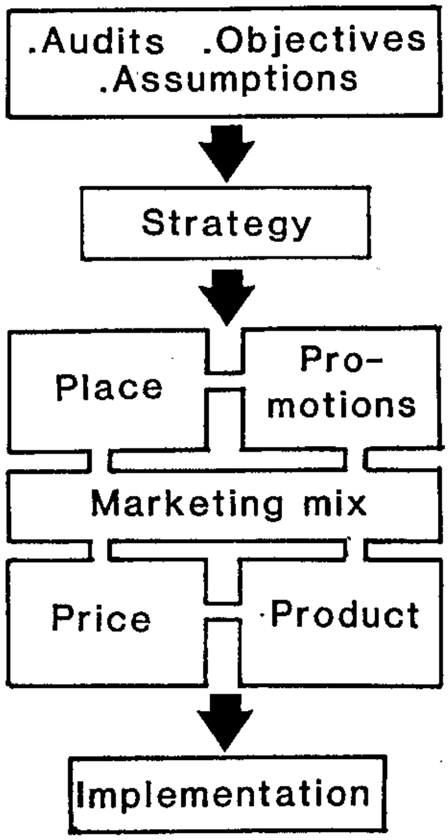

FIGURE 8.4 The market planning process.

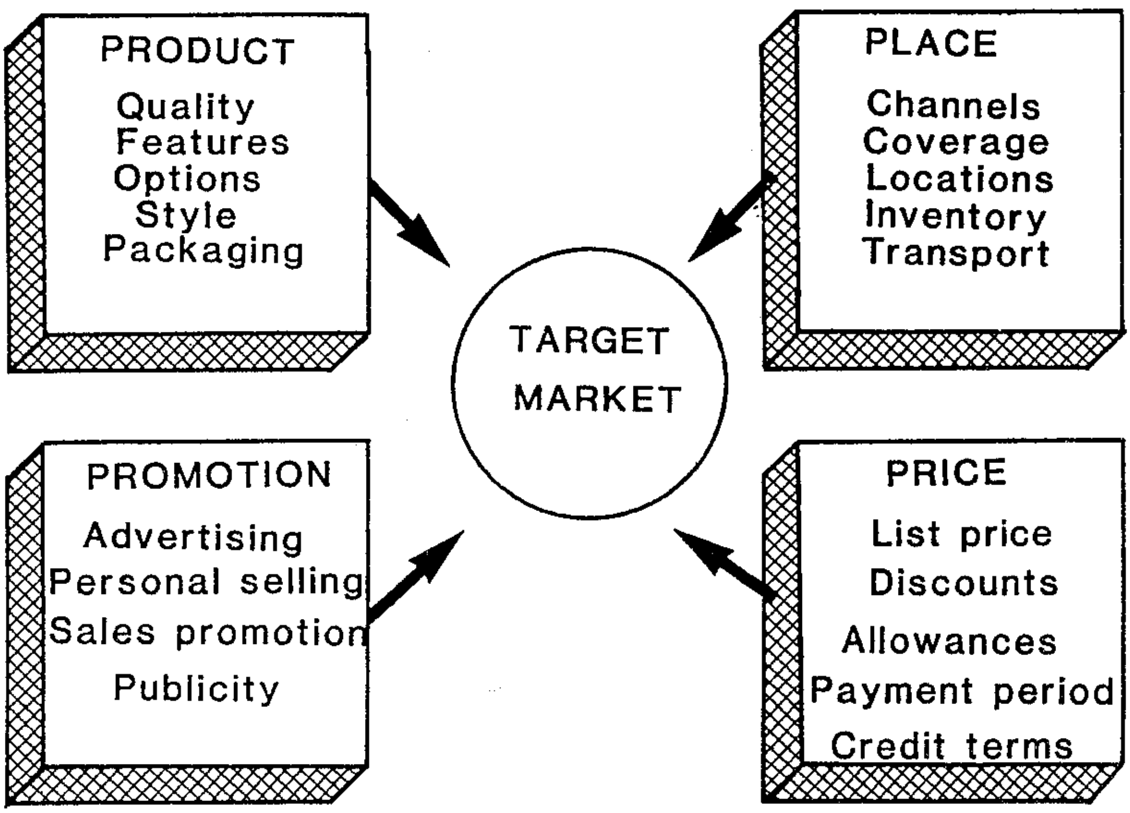

FIGURE 8.5 The variable tools of marketing.

Pertinent questions which help to establish the appropriateness of a producers current product-market strategy include the following:

- what benefits do the customers seek in the product?
- does the product provide these benefits better than those of competitors?
- what advantages or disadvantages do the competitors products have which are responsible for a gain or loss of market share?
- does the product range provide "value-in-use" to customers in relation to its cost?
- does each product in the range meet the set corporate objectives?

The answers to these questions will provide a basis for the development of an appropriate product-market strategy. Decisions on product-market strategy must be made in the context of a product range portfolio which should contain a suitable balance of growth products, mature as well as declining products (Christopher et al 1980).

<u>Product life cycles</u>

The product life cycle as shown in Figure 8.6 must be evaluated. In the developmental stages of the sharptooth catfish industry the product will obviously be in the "introduction" phase. In this phase the market shows a period of slow growth during which profits are almost nonexistent. This is simply as a result of the fact that the company still has to recoupe the cost of product development and introduction. During this early stage only a few people (the innovators) buy the product. If the product is successful in the "introduction" phase it will inevitably move into the "growth" phase, when large numbers of people account for increasing sales, which in turn results in increased profit margins.

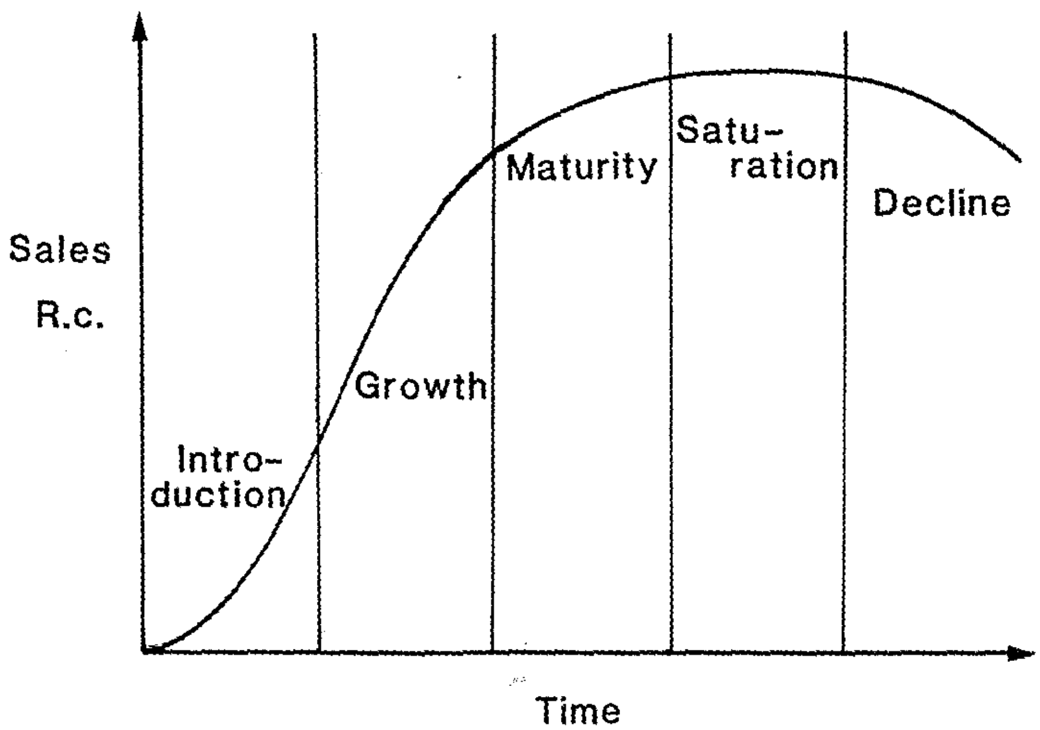

FIGURE 8.6 The product life cycle.

Another aspect which should be taken into consideration for the development of the sharptooth catfish market is product diversity. Reynolds (1965) argues that variety is a basic consumer demand. It thus makes more sense for a company to develop several products in each of its product lines. People who want variety would then be encouraged to switch within a company's product line and not seek other companies products (Barnett 1969).

New product development

During the development and the penetration phase of the sharptooth catfish into the existing fresh and processed fish market, the development of new products is of prime importance. Christopher et al (1980) stated that new product development can be seen as a process consisting of the following six steps:

1. Exploration - the search for product ideas to meet the company objectives.
2. Screening - a quick analysis of the ideas to establish those which are relevant.
3. Business analysis - examine the ideas in detail in terms of their commercial fit in the business.
4. Development - turning the idea into a saleable product.
5. Market testing - to verify earlier assessments.
6. Commercialism - full-scale product launch, committing the company's reputation and resources.

The stages for the development of a new product are discussed in detail by Day (1975), Rogers (1976), Boyd et al (1981) and are summarized in Figure 8.7 (after Christopher et al 1980).

Product pricing

To ensure competitiveness and profitability, Mason (1987) stated that price must be a balance between the market situation (competitor's prices,

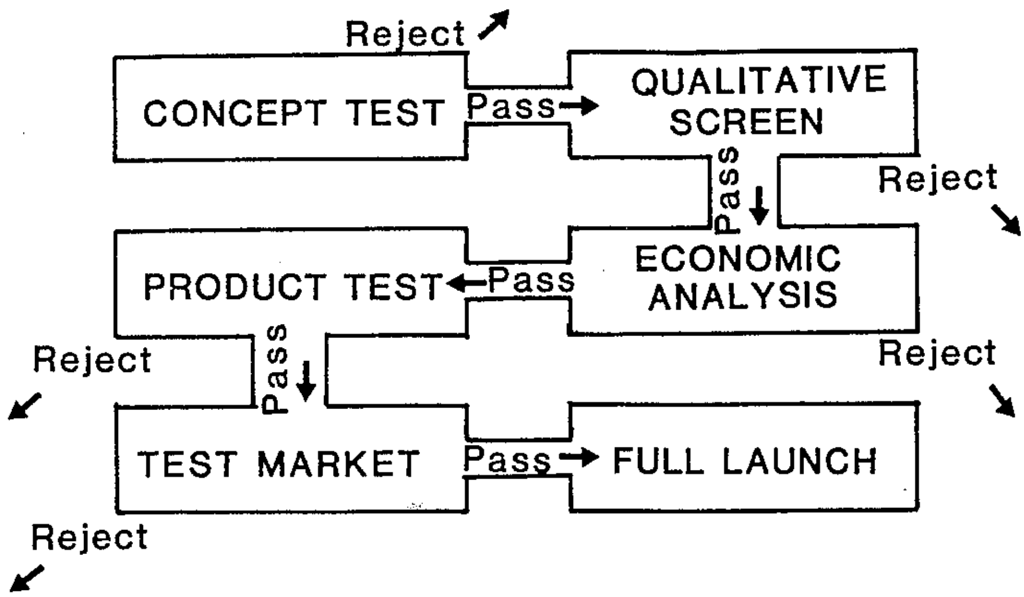

FIGURE 8.7 Stages in the development of a new product.

customer expectations and government restrictions) and internal cost of producing/procuring the product (including storage, sales and distribution costs). Pricing should therefore be an exercise in integration in which all relevant factors are taken into consideration. Nevertheless, the price must be in line with a predetermined pricing policy and set at a level to satisfy the pricing objectives. Other marketing variables also have to be taken into account. For example, if the quality of a producer's product, relative to a competitor's product, is perceived by the customer to be better, then a higher price is justified.

Another matter to be considered when pricing the product are cost increases. Such increases, for equivalent inputs, should not merely be passed on to the consumer but should be under recovered and accounted for via improved productivity. In this way profit levels can be maintained at the expense of competitors rather than at the expense of competitiveness.

According to Mason (1987) a number of important principles apply in developing a pricing system:

- pricing can never be professional unless the true costs are known.
- "thumb-suck" pricing is almost inevitable if a determined effort is not made to continuously collect market information, especially competitor's prices.
- without a formal pricing policy, price determination will be ad hoc, basically reacting to short-term triggers. Profit levels will thus be determined by competitors.
- a strategic and long-term plan is necessary to ensure survival and growth.

Locality decisions

Where the customer purchases the products is determined by the outlet through which the products are available (Christopher et al 1980). It is, therefore, essential that the producers or the marketing company's distributive activity be based on a careful assessment of the market requirements and their ability to meet these requirements. The actors in the marketing channel form a network of institutions which themselves are linked by a series of mutually beneficial relationships. Therefore the marketing channel is purely the mechanism by which "the right product gets to the right place at the right time".

Promotion decisions

Modern marketing calls for more than presenting a good product, attractive pricing and making the product accessible to target customers. Companies must also communicate with their customers. In fact every successful company is inevitably cast into the role of communicator and promoter (Kotler 1984).

The producer or distributor of a new product, such as *Clarias gariepinus*, will have to manage a complex marketing communications system. The marketing communication mix consists of four major tools: i) advertising; ii) sales promotion; iii) publicity; and iv) personal selling. However, it is important to bear in mind that if the product is once bought and is disappointing to the customer no amount of advertising will convince the customer to try it again. It is therefore essential to supply a quality product from the outset. In addition a wrongly pitched price will switch off the firmest of consumer intensions and nonavailability on the shelves is a gift to the competition.

Advertising alone or in combination with any of the other variables in the promotion mix may thus be a powerful tool in order to build a market for *Clarias gariepinus*. It is also of value in the distribution of the product (Aspinwall 1961).

PRESENT STATUS OF *CLARIAS GARIEPINUS* MARKETING IN SOUTH AFRICA

The farming of sharptooth catfish in South Africa, although still in its infancy, is growing rapidly. As shown above it is essential that special attention be given to marketing aspects of this new product. Presently the geographic locality of the operation and whether the catfish in a particular area is a "known" entity largely determines the way in which it is marketed. In the Transvaal lowveld catfish are either sold live, directly from the pond or are delivered to a cooperative processing unit, from which the products are distributed to more sophisticated markets. This is in stark contrast to the northern Cape area where catfish have to be skinned, filleted, chilled and packed. The sale of live or whole catfish in this area is not economically feasible. Nevertheless some important milestones have been reached with the marketing of sharptooth catfish in that the demand is presently greater than the supply.

CONCLUSION

It is evident that the long-term success of *Clarias gariepinus* marketing will to a large extent be determined by effective marketing management practices.

If the marketing of sharptooth catfish is correctly approached and executed it has a tremendous potential in becoming a very sought-after product by consumers and a profitable product for the producers.

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CHAPTER 9. BACTERIAL AND VIRAL DISEASES OF *CLARIAS GARIEPINUS*

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INTRODUCTION

Before considering the bacterial and viral diseases which do, or may occur in *Clarias gariepinus*, it is advisable to review some of the definitions of disease in fish and consider some of the health risks in intensive farming. Bacterial and viral diseases in fish often have characteristic signs. The observant farmer can prevent a major disease by noting these signs and taking appropriate action.

A disease in a fish is the end result of an interaction between at least three factors: host susceptibility; pathogen virulence and environmental factors (stressors) (Wedemeyer et al 1976). The importance of environmental stress on the outcome of the encounter between a pathogen and a susceptible host cannot be overemphasized. Fish kept under intensive conditions are constantly exposed to a wide range of stressors and the fish will attempt to adjust physiologically. However, any stressor that exceeds the fish's ability to adapt may be lethal or will facilitate the infection by opportunistic pathogens which may be present in the water (Wedemeyer 1970).

HEALTH RISKS IN INTENSIVE FISH FARMING

Under intensive fish farming conditions fish are confined and concentrated in a more or less unnatural environment. This may affect the health of a fish in a number of different ways.

In large bodies of water, environmental conditions are normally stable. If these conditions change, the fish can move away to areas where the stressors are reduced. However, in small bodies of water eg in hatcheries or production ponds environmental conditions may change rapidly, with no avenue of escape for the fish. In addition to this, many man-made stressors, such as handling and feeding are brought to bear on the fish. This stressful situation may be sufficient to trigger off a disease episode in the population. (Roy Kannemeyer of Cliff Fisheries in Kimberley has observed adult sharptooth catfish to actually leave the ponds when ammonia levels exceed 7 ppm. Does anyone still dare to question the intelligence of this amazing fish? - Editor).

The high population densitites under which fish are grown on a fish farm are also relevant as regards the outbreak of a disease. High population densities results in increased levels of metabolic wastes and decreased levels of dissolved oxygen. High population densitites also greatly facilitate successful transmission of a pathogen from one fish to another by increasing the possibilities of an infected fish coming into contact with a susceptible one. Farming fish under intensive conditions, therefore, places tremendous stress on the fish and greatly facilitates infection by pathogens.

SIGNS OF BACTERIAL AND VIRAL INFECTIONS

One of the most characteristic signs of a bacterial or viral infection is an exponential increase in the mortality rate. As soon as the farmer notices an increase in the mortality rate, he should seek help. Sudden mass mortalities are normally caused by environmental factors such as sudden drops in temperature or toxic substances in the water.

Generally, the symptoms of an infectious disease in a fish are nonspecific and not indicative of the causative agent. Signs such as lethargic movement, pop-eye, haemorrhages at the base of the fins, enlarged spleen, haemorrhages in the internal organs, accumulation at water out-flows and erratic swimming motions could indicate the presence of an infectious disease in the population.

DISEASE OF *CLARIAS GARIEPINUS*

There is very little information on bacterial or viral diseases in *C gariepinus*. Two syndromes of unknown etiology are found in sharptooth catfish. The first, which occurs mainly during the fingerling stage, concerns a rupture in the caudal part of the intestine. It is known as "Ruptured Intestine Syndrome" (Viveen et al 1985; Boon and Ooschat 1986; Boon et al 1987; Huisman and Richter 1987). It develops mostly in fish between three to five grams at high feeding levels and can result in mortalities of up to 70% (Huisman and Richter 1987). The second syndrome concerns the destruction of the arborescent organ (air breathing organs) of the fish, which leads to inflammation of the skull resulting in a lateral skull break. It is known as "Broken Head Disease" and can occur in fish larger than 10 cm (Viveen et al 1985; Huisman and Richter 1987). A similar syndrome has also been reported for *C batrachus* and *C macrocephalus* in Asia (Kabata 1985).

There are a number of possible reasons for the paucity of information on diseases in *C gariepinus*. The first reason could be that all factors needed for a disease are not present. It is well known that *C gariepinus* is particularly hardy and can survive adverse environmental conditions (Bruton 1979; Clay 1977) without apparent signs of stress. As stated above, stress is often an essential requirement for diseases in fish.

Another possible reason for the lack of information on infectious diseases in *C gariepinus* is a paucity of specific pathogens. This, however, is unlikely. Other species of fish, such as trout and channel catfish have their own spectrum of diseases which have been isolated and identified after these species were intensively cultured. As *C gariepinus* is indigenous to Africa, it is very possible that a unique set of pathogens have evolved alongside the fish. The presence of these pathogens may only become apparent once the fish is subjected to intensive culture conditions.

The third, and most likely reason for the lack of information is the age and extent of the industry. The first investigations into the suitability of *C gariepinus* as a candidate species for aquaculture were undertaken in 1960 in Egypt (El Bolock and Koura 1960). Only after the development of artificial hormone induced spawning techniques, have sufficient fry been produced to facilitate farming with this species (Hecht 1985). When this is compared to the trout industry which was started in Denmark in 1890 (Maurer 1969), the sharptooth catfish industry is still in its infancy.

According to Wolf (1966) most of the information on viruses of fish is from cultured species. This is also true for bacterial diseases. A wealth of information is available on diseases of trout, salmon and channel catfish and this is due mainly to the age and extent of the different industries.

POSSIBLE DISEASES OF *CLARIAS GARIEPINUS* IN SOUTH AFRICA

As mentioned above it is very possible that *C gariepinus* has a host of indigenous pathogens which may be identified once this species has been cultured intensively for some time. Apart from any indigenous pathogens, other pathogens may be introduced into the country. Some pathogens of channel catfish or trout could be capable of causing a disease in sharptooth catfish. It has been found for example, that channel catfish virus is capable of infecting cells of *C batrachus* (Noga and Hartmann 1977).

A host of normal environmental bacteria, such as *Aeromonas* species, *Pseudomonas* species, *Vibro* species and *Flexibacter columnaris*, are well known opportunistic pathogens of fish and may be capable of infecting *C gariepinus* if all of the conditions needed for a disease are present.

CONCLUSION

There is very little information on diseases of *C gariepinus*. This may be due to a lack of pathogens, which is unlikely. It could also be due to the fact that the fish has not been intensively cultured for a long enough time and have not therefore been subjected to the stressors associated with this type of farming. The possibilities for disease, however, do exist and the farmer should be on the look-out for any signs. Care should also be taken not to introduce pathogens into the country with other species eg channel catfish.

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CHAPTER 10. PARASITES OF SHARPTOOTH CATFISH AND THEIR POSSIBLE IMPLICATION IN AQUACULTURE

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INTRODUCTION

In the past decade, considerable attention has been given to the study of parasites of South African inland freshwater fishes, in particular cichlid fishes (Basson et al 1983; Britz et al 1984, 1985; van As and Basson 1984; van As et al 1984; Avenant and van As 1985). Very little attention has, however, been given to the parasite fauna of the African sharptooth catfish, *Clarias gariepinus*.

A project is currently in progress with the aim to synthesize existing information on African cichlid and clariid diseases. The text below summarizes some of the findings within the realm of this project.

PROTOZOANS

A variety of protozoan parasites are associated with freshwater fishes and have been implicated in diseases and mortalities. Of these, the more common parasites are the sessile ciliophorans, trichodinids, *Chilodonella* and *Ichthyophthirius multifilis*. These parasites are distributed widely on wild as well as cultured fishes, and may under adverse environmental conditions be responsible for stock losses. With the exception of *Ichthyophthirius*, which is responsible for white spot disease, low consentrations of these animals rarely cause severe pathology on large fish. In the case of larvae, however, even mild infestation may result in high mortalities.

In the case of sharptooth catfish collected from the wild, infestation levels on large fish appear to be low, and there seems to be no pathology. In larvae and fry maintained under laboratory conditions, however, various species of the above mentioned protozoans have been found to parasitize the catfish. Under hatchery conditions, high infestations of protozoans may result in severe losses. The parasites involved are found on the skin as well as the gills, and although no specific research on their effect on catfish larvae has as yet been carried out in South Africa, the pathology will most probably be the same as on other cultured fish species (Paperna and van As 1983).

Treatment of ectoparasitic protozoans can be achieved by the use of chemical such as malachite green and formaldehyde applied directly to the water. The treatment is well documented in various textbooks (eg Paperna 1980), but care should be taken in administering the dose as the larvae might be severely affected by the chemicals. It was shown by van As et al (1984) that the concentrations of formalin to eradicate protozoans on carp and tilapia under South African conditions differ from the concentration used under Israeli conditions. As yet no treatment trials with *Clarias* *gariepinus* in South Africa have been carried out. If outbreaks of these parasites occur, farmers would be well advised to test the toxicity of the chemicals on a small sample of larvae or juveniles before applying treatment to ponds. For more detailed information concerning treatment of fish, refer to Paperna (1980), van As et al (1984) and van As and Basson (1988). (See also the Table appended to the end of this chapter.

FUNGAL INFECTIONS

The ubiquitous opportunistic fungi of the genus *Saprolegnia* are commonly found in focal infections on the skin of large catfish maintained in aquaria. In many cases *Saprolegnia* appeared shortly after collection and transport of catfish. This may be the result of injuries sustained in the handling process, which were then secondarily infected by opportunistic and facultative fungi. Ova and larvae of catfish reared in our laboratory were also susceptible to fungal infections, which proved to be difficult to treat effectively. In our opinion fungal infections may prove to be an important restraint to catfish rearing, since it is difficult to treat and spreads rapidly in culture tanks.

Schoonbee et al (1978) treated holding tanks either with formalin or a mixture of formalin and malachite green as prophylactic treatment against protozoan and fungal infections during the rearing of chinese carp species. This treatment of a mixture of formalin and malachite green, however, killed catfish fry within two days of application (Schoonbee et al 1980). According to van As et al (1984) a concentration of 25 ppm of formalin, as used by Schoonbee, proved insufficient to eradicate either protozoans or *Saprolegnia*. It is therefore extremely important to take note of the fact that the concentration of formalin required to control protozoans is higher than the tolerance limit for catfish larvae. In this case it would be important to prevent rather than to treat fungal and protozoan infections.

MONOGENETIC TREMATODES

Dactylogyrid monogenetic trematodes, which commonly coexist with trichodinid protozoans, have been found on the skin and gills of catfish fry in the hatchery at the Department of Ichthyology and Fisheries Science, Rhodes University. These monogeneans caused severe mortalities of the fry. The treatment of these organisms is the same as those used for protozoans. Once again it should be emphasized that extreme caution should be taken as the parasites might require a concentration of chemicals higher than the tolerance level of the fry. Apart from this record, no published information concerning monogeneans of catfish are available for South Africa. It is, however, highly likely that one or more species may be found on wild fish, which under culture conditions could result in stock losses. (Monogenean trematode induced mortalities also appear to be related to poor feeding regimes).

DIGENETIC TREMATODES

A number of trematode metacercaria have been reported to infect catfish collected from the wild (Mashego 1977; van As and Basson 1984). These trematodes are transmitted by snails, acting as an intermediate host, and in many cases require a piscivorous bird as final host to complete the life cycle. Infections of wild sharptooth catfish are mostly sporadic depending on the presence of the intermediate snail host. Very few, if any, small catfish under 150 mm bear any significant metacercarial infections in the wild. As yet, digenetic trematodes have not occurred in sharptooth catfish under culture conditions in South Africa.

In the case of tilapia culture, heavy infections of clinostomatid trematodes occurred in ponds at Tompi Seleka (Britz et al 1985) where an abundant snail population occurred in ponds. This infection was easily eradicated by breaking the life cycle via the removal of the snails and employing various techniques to discourage birds from frequenting the ponds.

The occurrence of severe infections by digenetic trematodes in fish ponds was recently found in Mauritius at a government fish farm. Here severe infection by *Centrocestus* occurred on the gill filaments of various carp species. In this particular case an abnormally high concentration of snails (*Melanoides tuberculata)* occurred in the ponds, a situation which should be prevented when culturing fish. In our opinion, digenetic trematodes may be a potential problem for catfish farmers in the northern Transvaal, as various snails, including *M tuberculata* are abundant in this part of the country. Other digenetic trematodes, such as *Diplostomum* species, have been reported from the brain cavity and the lens of the eye, whilst *Phyllodistomum* was found in the bladder and *Glossidium* in the rectum of clariid fish (Mashego 1977). Good management under culture conditions can easily prevent the outbreak and the spread of digenetic trematodes by eliminating the snail intermediate host or by measures taken to scare off piscivorous birds.

The likelihood of humans being infected by trematode metacercaria is fairly high if the fish is eaten raw or only partially dried in the sun. although this phenomenon has not been reported from southern Africa, Witenberg (1944) recorded a case of acute pharyngitis caused by these parasites in a man in Israel. Different reports of clinostomatid trematodes maturing in domestic cats also appear in the literature (Belliappa 1944; Condy 1971). During surveys in the Caprivi, we found fish in the fish market still harbouring live trematodes. The likelihood of such infections transmitted to humans can therefore not be excluded.

CESTODES

A variety of tapeworms parasitize freshwater fish. Among these are larval worms like *Ligula intestinalis* that have a planktonic copepod as an intermediate host, whilst the adult worm can be found in piscivourous birds. Infections of larval cestodes are found sporadically in fish under natural conditions. These infections rarely reach epidemic proportions as the life cycle of the parasite is focused on preventing hyperinfections since the permanent hosts are not restricted to one habitat, but fly from any locality to another.

In the control of larval cestodes under culture conditions, it is best to break the life cycle by ensuring that the final host, the bird, cannot get into contact with the fish. To try and eradicate these cestodes is considerably more difficult than in the case of adult tapeworms, since the larvae do not occur in the intestine, but are found in the viscera. In the case of a tapeworm like *Ligula*, the larvae can be very big and this an seriously harm the infected fish.

Adult cestode tapeworms can also infect fish. These infections always occur in the intestine. A good example is the introduced *Bothriocephalus* which also has a copepod intermediate host. To date our research has shown that *Bothriocephalus* can parasitize any species of fish that feeds on plankton or ingests it by chance. *Clarias gariepinus* is an opportunistic omnivore, capable of filter feeding. If infected planktonic copepods were present, catfish would most certainly be an excellent host for the adult tapeworms.

In the case of the adult cestode, the breaking of the life cycle is more difficult, because both hosts, the copepods as well as the fish, occur in the same body of water. A variety of cases exist where *Bothriocephalus* infections have caused losses to fish farmers. During 1980, at the Lowveld Fisheries Research Station, *Bothriocephalus* caused a serious problem amongst carp (Brandt et al 1980).

This parasite can, however, be treated fairly easily by the use of tapeworm remedies like Lintex, which is mixed into the fish food. In the case of a serious outbreak of *Bothriocephalus* the pond must be drained in order to get rid of the infected copepods.

NEMATODES

Nematode infections are without doubt the most common of catfish and have been reported by Prudhoe and Hussey (1977) as well as by Mashego and Saayman (1980). During our surveys in the northern Transvaal every catfish examined had an infection of the larval nematode, *Contracaecum*, found attached to the viscera. The final hosts are piscivorous birds and probably also large vertebrates like crocodiles that feed on sharptooth catfish.

When catfish constantly feed on other fish that are also infected, the *Contracaecum* larvae are accumulated. The ingested worms migrate from the stomach to the viscera where extremely high numbers can occur. Although localized pathology and haemorrhaging occurs, the fish survive these enormous infections, although growth is impaired. A definite problem caused by *Contracaecum* is that high infections can cause sterility in the males, whilst some reports of female sterility are also known. Another problem is that where *Contracaecum* is present in high numbers, it would cause consumer resistance when fish are sold whole.

CRUSTACEANS

Under natural conditions, catfish can host a variety of crustaceans, like the branchiurns, *Argulus*, *Chonopeltis* and *Dolops* as well as copepods like *Ergasilus* and *Lamproglena*. No clear pathology has so far been noticed.

Some experimental work on *Argulus japonicus*, an exotic crustacean in South Africa, was undertaken at the Rand Afrikaans University. Although it was possible to develop a hyperinfestation in common carp we were only able to keep a small but steady population on sharptooth catfish. It seems as if some or other form of immunological response prevented it from reaching epidemic proportions. Although *A japonicus* causes severe pathology on fish like the carp we do not foresee it ever creating problems amongst adult catfish. However, larvae and juveniles might be susceptible, although our results show that small fish tend to clean one another effectively.

The branchiurn *Dolops ranarum* has been found mainly on two hosts by Avenant and van As (1985, 1986) in several surveys in the Transvaal. Firstly on *Oreochromis mossambicus*, where they are found in the mouth and secondly on catfish where they occur on the skin and in the branchial cavity. The biggest recorded infestation was 35 parasites on a very large specimen of *Clarias*. Pathology caused by these parasites consists of small lesions visible on the skin, which can cause secondary infections in some cases.

The control of crustaceans on adult fish, in general, is relatively easy with the use of insecticides.

CONCLUSION

The African sharptooth catfish, does not harbour any more or any less parasites than other fish species, (at least not in the wild). In some cases, such as with the nematode *Contraceacum*, an accumulation occurs with the result that large specimens appear to have a higher infection than smaller catfish.

Clarias gariepinus has a wide range of environmental tolerances and is therefore a very hardy animal. This, in our opinion, is to the advantage of the catfish culturalist. Fertilized ova and fry seem to be extremely vulnerable to therapeutic or prophylactic chemicals, which may be a problem when disinfection against parasites is necessary.

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APPENDIX

The following treatment table for some parasites has been drawn up by A T J Scholes. As pointed out by van As and Basson in Chapter 10 very few treatment trials have been undertaken in South Africa, therefore the dosage levels given in this table should serve only as suggested guidelines not absolute values, and should be used cautiously.

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PARASITES AND POSSIBLE TREATMENT STRATEGIES

FUNGUS	*Saprolegnia*
GROSS SIGNS	Skin and mouth lesions - patch or extensive, covered by cottony growth representing a mass of fungal filaments. May also be found on eggs and other animal material in incubation troughs prior to hatching.
TREATMENT	Fish: - in tanks - 0,15 ppm zinc free malachite green oxalate for one hour. - in ponds - 0,1 to 0,2 ppm zinc free malachite green for one hour. Repeat every third day until eradicated. Eggs: - 1 500 ppm malachite green oxalate dim, NO LONGER THAN 10 SECONDS or 0,1 ppm for one hour. Formalin at <25 ppm may also be employed. It should be noted that this should be a last ditch attempt as both formalin and malachite green at the concentrations necessary to kill this fungus is lethal to both fish and eggs. Prevention is better than cure and reasonable stocking densities coupled with a good feeding regime should be implemented along with good hygiene in the hatchery.

WHITE SPOT — *Icthyophthirius*

GROSS SIGNS

White spots (pustules) on skin, fins and gills.

TREATMENT

Treatment is difficult and requires a knowledge of the parasites life cycle. It is particularly important to remember that a single application or incomplete treatment will result in an accelerated wave of reinfestation as dislodging of the trophozoites (spot) induces their repro duction into tomites (the free swimming stage). The treatment strategy should be designed to eliminate the emerging free swimming tomites. A formalin concentration of 200 ppm will effectively dislodge the trophozoites. A dose of 0,1 ppm to 0,15 ppm malachite green or a cocktail of 0,05 ppm malachite green and 50 ppm formalin once the trophozoites have been dislodged, should effectively kill most of the free swimming tomites. This strategy should be repeated until the infection is completely eradicate.

PROTOZOA — *Trichodina*

GROSS SIGNS

Changes in skin - including abnormal colouration, skin maybe covered by a greyish white mucoid film. This parasite is often found in conjunction with the monogenetic trematodes discussed later.

TREATMENT

45 to 50 ppm formalin as a matter of routine, usually a single application is sufficient. This concentration should be maintained until all parasites have been eradicated.

MONOGENEAN TREMATODES — Dactylogyrids

GROSS SIGNS

Infect gills which may appear pale or be covered by whitish patches of tissue. The elongated worms can be observed on the gill surface.

TREATMENT

Dactylogyrids are most successfully treated with organophosphates, particularly Bromex - 0,12 ppm Active Ingredient (A.I.) and Dipterex - 0,25 to 0,5 ppm A.I.

Gyrodactylus

GROSS SIGNS

In heavy infections the skin may be covered by a thick greyish white fluff, and it may appear irritated and haemorrhagic. The cornea of the eye may become opaque. Excessive mucous production coupled with signs of irritation and restlessness in the fish may also be observed. Swarming worms up to one millimetre long may be observed on the skin. No signs are evident when gills are infected.

TREATMENT

A short saline bath (two per cent) may be all that is required. However, as it is often difficult to distinguish between an infection of this parasite and *Dactylogyrus* it is advisable to make use of organophosphates in treating this disease, at the same dosages indicated above. The application of chlorinated lime to an empty pond at a rate of 500 kg ha^{-1} will effectively kill the eggs of this parasite. So if the reoccurrence of this parasite is a perennial problem liming should be undertaken as a matter of routine.

TREMATODE METACERCARIAE

Black spot

GROSS SIGNS

Very distinct black cysts on the skin, coupled with less distinct nonpigmented cysts. Heavy infection in the gills results in thickening and deformation of the filaments. Eye infections cause a whitening of the lens. Internal infections are evident as black spots in the muscle.

TREATMENT

There are no known methods of direct control. Breaking the life cycle through the elimination of the definitive snail host is the only option in eradicating this parasite. Unfortunately no work has been done to eliminate the definitive host.

Copper sulphate is a widely used molluscicide, with toxicity ranges varying from 6 ppm to 24 ppm. High loads of organic matter in the water reduces the activity of copper sulphate so that even the above concentrations may be ineffective. Unfortunately fish will only tolerate concentrations of copper sulphate in the region of 10 ppm, so that eradication of the snails will require removal of fish from the pond. Application of this treatment is thus best undertaken routinely when ponds are drained and prepared for restocking.

It has been reported that effective control of snails may be achieved by a continuous application of low concentrations of copper sulphate, about 1 ppm in hard waters and 0,125 ppm to 0,3 ppm in soft waters. Alternatively low soluble formulations of copper carbonate and copper oxide have been recommended as molluscicides as they do not seem to have much affect on fish. However, they have a long residual effect on the environment and could suppress the natural productivity of a pond.

The carbamates Rhodiacid and Sevin are considered as molluscicides with no effect on fish if applied at concentrations of 20 g m^{-2} and 0,1 to 0,15 g m^{-2} respectively. Unfortunately data on the practical use of these chemicals are not available and they should be avoided if possible until such time as their effects have been established.

Another potentially suitable molluscicide is a stomach poison, five per cent Baylucide formulation, either in a heavy granulated form or with an attractant acrylic polymer as snail bait. However, poison may be detrimental to bottom feeding fish.

Finally the eradication of vegetation from the banks of a pond thus depriving the snails of their habitat may be feasible. This is not considered to be too effective.

NEMATODE WORMS — Round worms

GROSS SIGNS — The worms are found in the abdominal cavity of the fish.

TREATMENT — Environmental prophylaxis is difficult as short of eradicating the pisciverous birds which are the definitive host of this parasite there is not much that can be done. However, there is every indication that an infection of nematode worms goes unnoticed by the fish, and no loss of condition occurs. They are also not harmful to humans, however, their presence should be borne in mind when processing and marketing the fish.

APPLICATION OF THERAPEUTIC CHEMICALS

a) In tanks - flush treatment: shut off water supply for required time. Add stock solution to the tank to produce the required concentration. Flush away by resuming water flow.

b) In ponds with constant water exchange: add stock solution to incoming water gradually to produce the specific concentration. in the water for the desired time.

c) In ponds with little or no water exchange: add stock solution to the pond to produce the required concentration. The chemicals should breakdown within 24 hours. The dosage should be calculated bearing this in mind.

NOTES

Toxicity of formalin increases with temperature. Higher temperatures reduce the effectiveness of organophosphates.

The toxicity of formalin and copper sulphate is reduced with increased salinity.

The lower the pH the higher the toxicity of copper sulphate.

Low water hardness increases the toxicity of copper sulphate.

Organic matter and suspended matter reduces the activity of copper sulphate. Formalin may react with other chemicals naturally in the water to form compounds toxic to fish particularly metabolic products and excess food.

Application of formalin and copper sulphate have a depleting effect on the oxygen regime.

Formalin and copper sulphate kill zoo- and phytoplankton as well as benthic invertebrates thus having a detrimental effect on ponds productivity. Organophosphates create environmental problems as a result of the accumulation of certain hydrocarbons in the microfauna of the pond.

Reduction of stocking densities and attention to diet are often solutions to parasite problems as this reduces the stress on fish making them less succeptible to disease. Particular attention should be paid to hygiene, especially in the hatchery situation.

A.I. or Active Ingredient is that ingredient in a chemical compound which has been identified as the actual ingredient which kills the particular parasite concerned. For example, Dylox is the trade name of an organophosphate powder. It contains Dipterex which has been found to kill monogenean trematodes. When making up a 0,5 ppm solution of Dylox one would work out the weight of compound required based on the percentage of Dipterex in Dylox and not Dylox as a whole.

CHAPTER 11. CRYOPRESERVATION OF *CLARIAS GARIEPINUS* SPERM

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INTRODUCTION

Adequate artificial spawning techniques for *C gariepinus* now exist to ensure a sufficient supply of fingerlinges to prospective fish farmers (Schoonbee et al 1980; and Chapter 4). A recent development to assist in the controlled propagation of fish is the cryopreservation of sperm and ova. The cryopreservation of sperm can be of practical value, for it allows banking of sperm which could be used in the manipulation of spawning programmes (Harvey 1982). Furthermore, cryopreservation is also a useful tool in genetic selection of fish. In recent years substantial progress has been made on the cryopreservation of sharptooth catfish sperm and successful fertilization experiments have been undertaken. However, there is still room for improvement of existing techniques (Steyn and van Vuuren 1987a; van Vuuren and Steyn in press).

CRYOPRESERVATION TECHNIQUES

Fresh sperm from a ripe running fish is preferred although spermiation can be induced by artificial stimulation with human chorionic gonadotrophins and catfish pituitary homogenate (Steyn and van Vuuren 1987b). A male to be artificially stimulated is selected principally on the basis of the size and reddening of the genital papilla. Milt is collected by dissecting out the testes, making an incision along the medial side whereupon the milt can be squeezed out. The milt is then prepared for preservation by mixing it with a cryodiluent in a 1:1 ratio. An equilibration period of 20 minutes is allowed before the start of the freezing procedure. The cryodiluent consists of a cryoprotector (glycerol) and an extender (glucose) which is prepared by the addition of 11 ml (88%) glycerol to 89 ml (four per cent) glucose. Aliquots of 0,3 ml from the cryodiluent are pipetted into one millilitre cryotubes, after which milt samples of 0,3 ml are added to each cryotube. The cryotubes are then transferred to the freezing chamber of a computerized freezing unit and frozen at a predetermined freezing rate (Figure 1). Alternatively, freezing can also be carried out by adding quantities of dry ice to isopropanol in a widenecked thermos flask, in which the cryotubes are placed (Steyn et al 1985). The samples are transferred into liquid nitrogen after -70°C is reached. Cryopreserved milt samples are thawed in a waterbath at 25°C just prior to fertilizing the ova. Only good quality milt with high sperm counts and motility must be used. The quality of sperm is assessed by determining total motility, motility grade and percentage motile spermatozoa before and after freezing. Motility is evaluated microscopically by using a five-stage scale (Chao 1982). The induction, stripping, fertilization and incubation procedures described in Chapter 4 are then applied.

CRYOPRESERVATION SUCCESS

Sperm of the sharptooth catfish can be stored in liquid nitrogen for prolonged periods and still remain fertile. After 28 months of preservation the fertilization of ova can be as high as 82%.

Care must be taken that overripe ova are not used and that the interval between stripping and fertilization of the ova is kept to a minimum. Spontaneous development of ova occurs in the sharptooth catfish. However, unfertilized ova start to die after the first 12 hours of development (Steyn and van Vuuren 1987a). This phenomenon must be taken into consideration in assessing the fertilization success. Sperm survival decreases between 24 hours and 14 days after cryopreservation. Thereafter survival is unaffected up to 28 months. Figure 11.1 describes the optimal freezing rate for sharptooth catfish sperm.

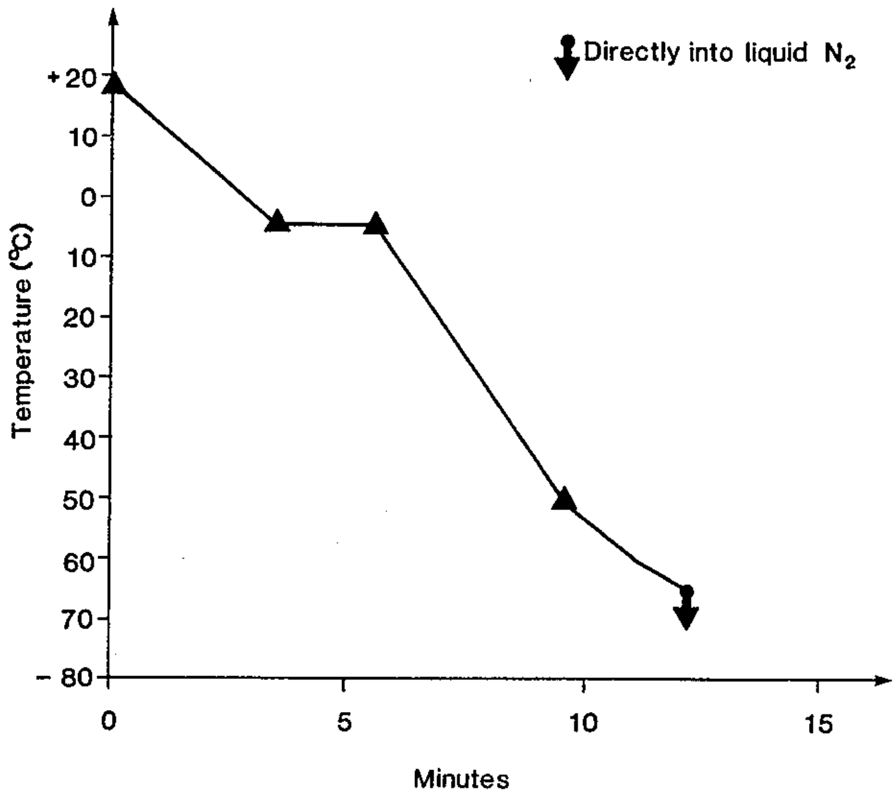

FIGURE 11.1 The optimal freezing rate for *Clarias Gariepinus* sperm.

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CHAPTER 12. FINANCIAL PLANNING

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INTRODUCTION

Many motivations for the development of an aquaculture venture can be offered, the most common of which is perhaps the (mis)conception that aquaculture can provide cheap protein for the hungry masses. Such philanthropic logic and the exciting prospects of engaging in a new and dynamic venture are often enough to convince investors to part with their money. No matter how exciting the prospects, (and the prospects of *Clarias gariepinus* culture certainly do seem exciting) the viability of a venture is determined solely by its profitability. The philanthropic approach should be reserved for rural aid programmes and the like, but a more capitalistic approach should be the driving force behind any developing industry.

This rather cynical introduction sets the stage for the attitude which should be adopted while engaging in the dangerous paper exercise of financial planning. For each potential aquaculture venture all of the economic facets must be considered before a final decision about possible development is made (Shang 1981; Klemetson and Rogers 1985).

FACTORS AFFECTING THE ECONOMICS OF CATFISH CULTURE

Intensive catfish culture is a production orientated business and the final analysis of its profitability can be reduced to the simple equation, Y=QP - C (Shang 1981), where Y is the producers profit or net income per unit of land or water area, Q equals production, P is the price received and C is the cost of production and marketing. The factors influencing the variables Q, P and C need to be studied in detail in order to make a realistic assessment of Y and also to form a basis for planning the scale of the intended operation. Figure 12.1 presents an outline of the major factors affecting the economics of catfish culture.

The equation Y=QP - C may be simple but its implications (Figure 12.1) are profound, and all planning and management strategies should be based thereon. Consider the hypothetical case of a venture which is floundering due to marginal profits. The instinctive reaction would be to attempt an increase in production (Q), not realizing that this implies and increase in costs (C) which tends to negate the benefits. The equation Y=QP - C signifies that time would be much better spent in attempting to increase the selling price (P). This is illustrated by the following example. For arguments sake let us assume that there is a linear relationship between production (Q) and cost (C) in a situation where it costs 90 units to produce 100 units of fish which is sold at a unit price of 1. If these values are substituted into the equation we obtain: Y=100 X 1 - 90 = 10

If production is increased by 50% the equation reads:
Y=150 X 1 - 135 = 15 which yields a 50% increase in profit.

TABLE 12.1 Annual financial planning for different scale catfish farms

1: PROJECTED ANNUAL INCOME	1	2	3	4	5
Production (tons)	300	150	100	100	50
Unit price (R/live kg)	2,20	3,00	3,00	2,60	2,60
Revenue	660 000	450 000	300 000	260 000	130 000
2: INITIAL CAPITAL INVESTMENT					
Property	300 000	300 000	100 000	0	0
Vehicles	80 000	40 000	40 000	15 000	15 000
Hatchery	40 000	40 000	0	0	0
Earthen ponds	100 000	50 000	40 000	40 000	20 000
Surveying	2 000	1 000	800	800	400
Plastic pools	4 000	2 000	1 000	1 000	500
Feed plant	60 000	60 000	0	0	0
Plumbing	24 000	12 000	10 000	10 000	6 000
Pumps	3 500	3 500	3 500	3 500	3 500
Tractor	40 000	40 000	20 000	0	0
Computer equipment	4 500	4 500	4 500	0	0
Office equipment	10 000	10 000	10 000	0	0
Electrical installations	1 600	1 600	1 600	1 600	0
Various	10 000	10 000	10 000	10 000	5 000
Total	679 600	574 600	241 400	81 900	50 400
3: ANNUAL OPERATING COSTS					
Property rent	0	0	0	6 000	3 000
Labour	49 000	26 500	19 000	19 000	11 500
Salary of mgmt Personnel	60 000	60 000	60 000	60 000	30 000
Scientific research	1 000	1 000	1 000	1 000	0
Interest on debt	60 000	60 000	30 000	10 000	6 000
Transport	36 000	21 000	16 000	16 000	11 000
Travel	6 000	3 000	2 000	2 000	1 000
Feed components	234 000	117 000	78 000	78 000	39 000
Fingerlings	0	0	15 000	15 000	7 500
Electricity	3 000	3 000	1 500	1 500	700
Water	1 000	1 000	1 000	1 000	500
Insurance	9 000	4 500	3 000	3 000	1 500
Maintenance and repairs	9 000	4 500	3 000	3 000	1 500
Chemicals	1 500	750	500	500	250
Entertainment	3 000	1 500	1 000	1 000	500
Legal expenses	200	200	200	200	100
Post and telecom	3 000	3 000	3 000	3 000	500
Depreciation	36 960	26 460	13 140	7 190	4 540
	512 660	333 410	247 340	227 390	119 090
4: EVALUATION					
PROFIT BEFORE TAX	147 340	116 590	52 660	32 610	10 910
COMPANY TAX (50%)	73 670	58 295	26 330	16 305	5 455
AFTER TAX PROFIT	73 670	58 295	26 330	16 305	5 455
RETURN ON INVESTMENT (ROI)	10,8%	10,1%	10,9%	19,9%	10,8%
NET RETURN	11,2%	13,0%	8,8%	6,3%	4,2%

investment. Again this illustrates the importance of product price and marketing.

In the third example, it is assumed that fingerlings and feed can be purchased as required, and a hatchery and feed plant would not have to be built. At a product price of R3,00 kg^{-1} it appears that an annual production of 100 tons would suffice for a similar return on investment in comparison to examples one and two. The fourth and fifth examples illustrate the advantages of integrating catfish culture with an existing agricultural venture such as irrigated crop farming. A new property would not have to be purchased and costs could be reduced due to sharing of common resources (vehicles, water, administration etc). This allows for a considerable reduction in the scale of the operation.

All the examples in Table 12.1 predict only marginal returns, and none of the options seem financially attractive. This was purposely done so as not to create the impression that catfish culture is more attractive than any other business. Table 12.1 should only serve as a guideline for financial planning and as a framework for acquainting oneself with the effects of product price, production and costs on the economics of catfish culture. No general conclusion regarding the economic feasibility of *Clarias gariepinus* culture can be made at this stage, and each proposed venture should be evaluated by biotechnical and economic experts in order to provide accurate assessments of costs, production potential and marketability.

CASH FLOW PREDICTIONS

Financial planning, which is based on annual figures, (such as in Table 12.1) may be highly misleading. Even though it is possible at this stage to produce more than 25 tons ha^{-1} yr^{-1}, one needs to keep in mind that the fish only become marketable towards the end of the 12-month period and that the crop will not be marketed instantaneously. Due to the fact that marketing will have to be done on a continuous basis, a single, annual cycle of stocking, feeding and harvesting would be impractical. Several ponds will have to be stocked and harvested at different times, based on a carefully planned schedule in order to ensure continuous harvesting. A detailed cash flow projection is, therefore, a necessity. In most cases, even if a proposed project seems financially attractive on a year-to-year basis, a cash flow projection will indicate that the envisaged annual profits may not be realized until the third of fourth year of operation. In Chapter 5 a simple cash flow projection is presented in conjunction with an example of long-term production planning.

CONCLUSION

The financial planning of a catfish venture is, at this stage of the game, confounded by uncertainties regarding product price, production costs and production levels. Slight changes, in especially the first two factors, drastically affect the profitability of an operation. If for instance product prices are overestimated by 20% the projected profits may be as much as 300% overoptimistic. Therefore, any financial planning exercise should rather err on the side of conservatism.

Since feeding is the biggest production cost (Table 12.1), the feed cost to product price ratio is probably the most important factor determining the general economic feasibility of catfish culture. The ultimate success of commercial sharptooth catfish culture will depend not only on biotechnical aspects, which are extensively reviewed in these proceedings, but on the ability of entrepreneurs to widen the gap between feed price and product price.

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CHAPTER 13. AQUACULTURE REGULATIONS IN SOUTH AFRICA

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INTRODUCTION

Although there are no specific regulations for sharptooth catfish farming, there are numerous regulations which apply within the general area of aquaculture of which potential fish farmers should be aware of. This chapter attempts to identify the more important regulations and the organizations which should be consulted when plans are being made to develop, expand or operate an aquaculture venture. Most of these regulations are also applicable to catfish farming.

REGULATION OF AQUACULTURE IN SOUTH AFRICA

Industrial development necessitates the establishment of a system of regulations so as to ensure that each industry is politically, socially, economically and ecologically compatible with society's current operating requirements. Regulations are normally established through negotiation between producers of the product (private sector) and the government bodies/agencies which have been created to regulate the particular industry. As a consequence of changing socio-economic conditions, regulations are always in a state of evolution. Process is also a consequence of the continual interaction between producers and regulating authorities.

In most countries of the world, aquaculture is regarded as an integral part of agriculture as it involves the production and ultimately the harvesting of biological material (eg algae, fish shellfish or crustacea). Walmsley and Bruton (1986) have pointed out that the current regulations and interactions between producers and regulating agencies are far from satisfactory, mainly because of the lack of government input into the coordination and facilitation of regulatory issues. The probable reason for this is that the aquaculture industry in South Africa is still in its infancy. It is beyond the scope of this chapter to go into great detail on solutions to these current problems. At this stage one can only attempt to paint a scenario of the current status quo with the hope that the industry will press for an improvement in the situation.

There are numerous statutory organizations (central Government, provincial, municipal) concerned with the establishment and/or enforcement of regulations which are pertinent to aquaculture. With the Government's present move towards devolution of regulations there is much confusion as to jurisdictional responsibility. If one accepts that aquaculture is an agribusiness then it is convenient to consider regulations within several categories:

- site selection
- construction
- water supply
- organism to be cultured
- product processing and marketing

SITE SELECTION

Site selection is considered to be a critical factor as it plays a major role in determining both the initial and operating costs of the business (see also Chapters 3 and 12). However, what is often ignored is the fact that a site may be ideal, but cannot be utilized because of incompatibility with planned, existing or adjacent land usage. From a planning point of view central government (Department of Constitutional Planning and Development) has delegated its powers of regulation (The Physical Planning Act) to Provincial authorities. Each Provincial Administration has a Town Planning Ordinance which covers the regulations with respect to development within that province. In most areas of high development, local authorities (municipalities) have been required to allocate zones of land use and to compile an approved Town Planning Scheme. Changes to a designated land use within this Planning Scheme can only be made following application to and approval by Provincial Administration. Aquaculturalists should thus regard the respective Provincial Administrations as being central coordinators to whom application is made when plans are being prepared for consideration of a site. The Provincial Administration then seeks specialist opinion from other sources (eg Government and Provincial Departments) before giving approval. Municipalities (local government) who have prepared the Town Planning Scheme should also be viewed as being partners in this process.

Aquaculturalists should also be aware that the coastal zone is regarded as being an extremely sensitive development area and special regulations have been promulgated (Conservation Act 100 of 1982) to cover developments within the one kilometre strip above the high water mark along South Africa's coastline. There is also a Sea Shores Act which regulates any development in the sea below high water mark, but is also applicable to state ground above the high water mark. The responsibility for regulation of certain sections of the Sea Fisheries Act have been given to the Directorate of Marine Development (Environmental Affairs). The entrepreneur who wishes to establish a mariculture business in the sea (below the high water mark) must obtain a permit from this Directorate.

All Provincial Nature Conservation Departments have Ordinances which specify Fish Farming Regulations. These should be consulted as all have a clause, amongst others, which stipulates that no person shall establish a fish farm without the prior approval of the Provincial Administrator. Ordinances which apply are:

Natal - Ordinance No 15 of 1974
Transvaal - Ordinance No 12 of 1983
Orange Free State - Ordinance No 8 of 1969
Cape - Ordinance No 19 of 1974

CONSTRUCTION

Aquaculturalists should take note that although they are not necessarily (depending on the site) bound by municipal by-laws to construct facilities according to municipal regulations, there are still numerous regulations which will dictate construction characteristics. For example there are restrictions on reservoir and weir construction (see Water Act and Provincial Ordinances) which will influence the design. There might also be special regulations which apply to the organism, ie it might be a potential alien (marron) or a dangerous organism (crocodile) which then requires specific construction characteristics. For farmers who process their product, regulations might require the construction of specific facilities for handling, sterilizing or packaging of products.

WATER SUPPLY

Water is regarded as a strategic resource in South Africa and the Minister of Water Affairs has, in terms of the Water Act (Act 54 of 1956, as amended), the responsibility of allocating water to various sectors by means of permits. This is because the use of freshwater for aquaculture may indirectly compete with other sectors (Roberts and Bruwer 1986).

Any aquaculture enterprise must have access to a suitable and reliable source of water. This is usually available in the form of river, spring or reservoir water. Riparian properties usually have a water right and owners may use their rightful share of the water for aquaculture. Should an owner of a riparian property wish to use public water in areas which are not Government Water Control Areas (usually the so-called "surplus water"), then the provisions of Article 9(B) of the Water Act of 1956 apply. This article states that the owner who wishes to divert more than 110 litres of water per second or to store more than 250 000 m^3 of water requires a permit from the Minister of Water Affairs. In Government Water Control Areas both the construction of water works and abstraction of water are controlled.

A person who has a right to use public water for agricultural purposes, must apply for the Minister's permission in terms of Article 11(1A) to use this water for aquaculture. Aquaculture consumes a small portion of the water and the balance is returned to the river of origin. The permits in terms of Article 9(B) of the Water Act are therefore readily granted, but under strict provisions regarding pollution.

The practice of aquaculture results in nutrient enrichment and/or bacteriological pollution. Aquaculture has been defined in the Water Act as an industry ie it is considered to be similar to feedlots and chicken batteries with respect to the discharge of effluents. These considerations imply that if a person uses more than 150 m^3 of water per day for aquaculture, then permits for both the control of water use as well as effluent standards must be obtained. It is expected that exemption from prescribed standards may be granted to owners who use their irrigation water rights firstly for aquaculture and then for irrigation without any pollution load to the river. Requirements for the purification of wastewater or effluent have been published in the Water Act (1956) or additions (eg 18 May 1984).

ORGANISM TO BE CULTURED

Aquaculture often involves the culture of organisms which might not be indigenous to the country or area where the industry is situated. The topic of aquatic alien invasives is one which has received considerable attention in recent years (Bruton and Merron 1985). Invasive aliens can have harmful effects such as:

- habitat alteration
- introduction of parasites and diseases
- trophic alterations
- genetic pollution
- spatial alterations

Accordingly both central and provincial administrations are concerned about the introduction of aquatic aliens along with their potential to introduce parasites and diseases.

The regulation of aquaculture within the Departments of Agriculture (Agriculture and Water Supply - DAWS, and Agriculture Economics and Marketing - DAEM) is somewhat illogical at present. The Veterinary Services Section of DAEM is concerned with the importation of animals and animal products (Animal Diseases Act No 35 of 1984). However, the activity of this service is restricted to fish of the family Salmonidae (mainly trout and trout ova). The Plant and Seed Control Section of DAEM controls (Agricultural Pests Act) the importation of all other freshwater fish and aquatic organisms whether for culture or otherwise. In terms of section 3(1) of the Agricultural Pests Act, 1983 (Act 36 of 1983) no person shall import into the Republic any plant, pathogen, insect, exotic animal, growth medium, infectious thing, honey, beeswax or used apiary equipment except on the authority of a permit.

In terms of the Agricultural Pests Act of 1983 an exotic animal is defined as "any vertebrate member of the animal kingdom which is not indigenous to the Republic, and includes the eggs of such members, but does not include such a member which is an animal to which the Livestock Improvement Act of 1977 (Act 25 of 1977), applies or which is a fish as defined in Section 1 of the Sea Fisheries Act of 1973 (Act No 58 of 1973)."

Although the DAEM has its own laboratories, it currently lacks the ability to conduct certain diagnostic tests. Accordingly the research-orientated Fish Disease Unit of Onderstepoort (DAWS) provides a service facility for the diagnosis of certain parasites and diseases.

The importation of alien and exotic organisms is further complicated by the policies and regulations of provincial administrations who all have clauses within their ordinances to regulate the introduction of alien invasive species. At present the coordination and interaction between provincial and central administrations with regards to the approval of permits is rather confusing, as are the different policies of the respective provincial nature conservancies.

Clarias gariepinus is indigenous to South Africa and found ubiquitously throughout all of the provinces although not in all catchments. Therefore although it is not an alien, permits to culture this species have to be obtained from the respective provincial administrations in terms of the respective nature conservation ordinances.

PRODUCT PROCESSING AND MARKETING

The regulations governing product processing are well established and South African standards must rate as some of the most stringent in the world. In my opinion many processing plants in the United States of

America would fail to comply with South African health requirements. The regulations which apply include:

- Zoning of site. In terms of the Factory and Machinery Act the site must be zoned as industrial if products are to be transported from another area and processed on the site. Rezoning must be carried out according to the Provincial Town Planning Ordinance.

- Health requirements. Two Acts administered by the Department of National Health and Population Development apply. The Health Act (Act 63 of 1977) governs the hygiene in which the product is processed (eg gutted, chilled, packaged). The Foodstuffs, Cosmetics and Disinfectants Act (Act 54 of 1972) stipulates and regulates additives which assist with the preservation and taste of foodstuffs. Local authorities (municipalities) have been empowered to administer the Act.

- Standards. If the product is not frozen then only the regulations of the Department of National Health and Population need be considered. However, if the product is frozen or canned then the South African Bureau of Standards (SABS), by powers invested in it by the Department of Commerce and Industry (Standards Act No 35 of 1962, amended July 1973), must be consulted at the planning stage of the processing plant.

The Standards Act covers specifications for:

- general requirements for the factory;
- requirements for employees engaged in the preparation and processing of fish;
- conditions of ingredients used in the preparation of the product (eg salt, citric acid, glutamate, wood smoke);
- conditions of the fish;
- microbiological requirements;
- packing conditions;
- storage;
- delivery; and
- methods of chemical analysis.

The SABS specifications are stringent and require considerable input in terms of manpower and capital if they are to be met.

Most of these Acts also contain labelling regulations which stipulate that the packaging must contain a true description of the product, its origin etc, the details of which must not be misleading. In terms of sharptooth catfish therefore, the packaging or marketing of the product as "red snapper" or "freshwater kingklip" leaves the farmer liable to prosecution.

CONCLUSION

Although the aquaculture industry is in its infancy by comparison to other agricultural sectors (eg dairy, maize, wheat etc) there are well established regulations which ensure that developments are socially and economically compatible with present day South Africa. Some of the rules have therefore already been made, but what is lacking is their efficient

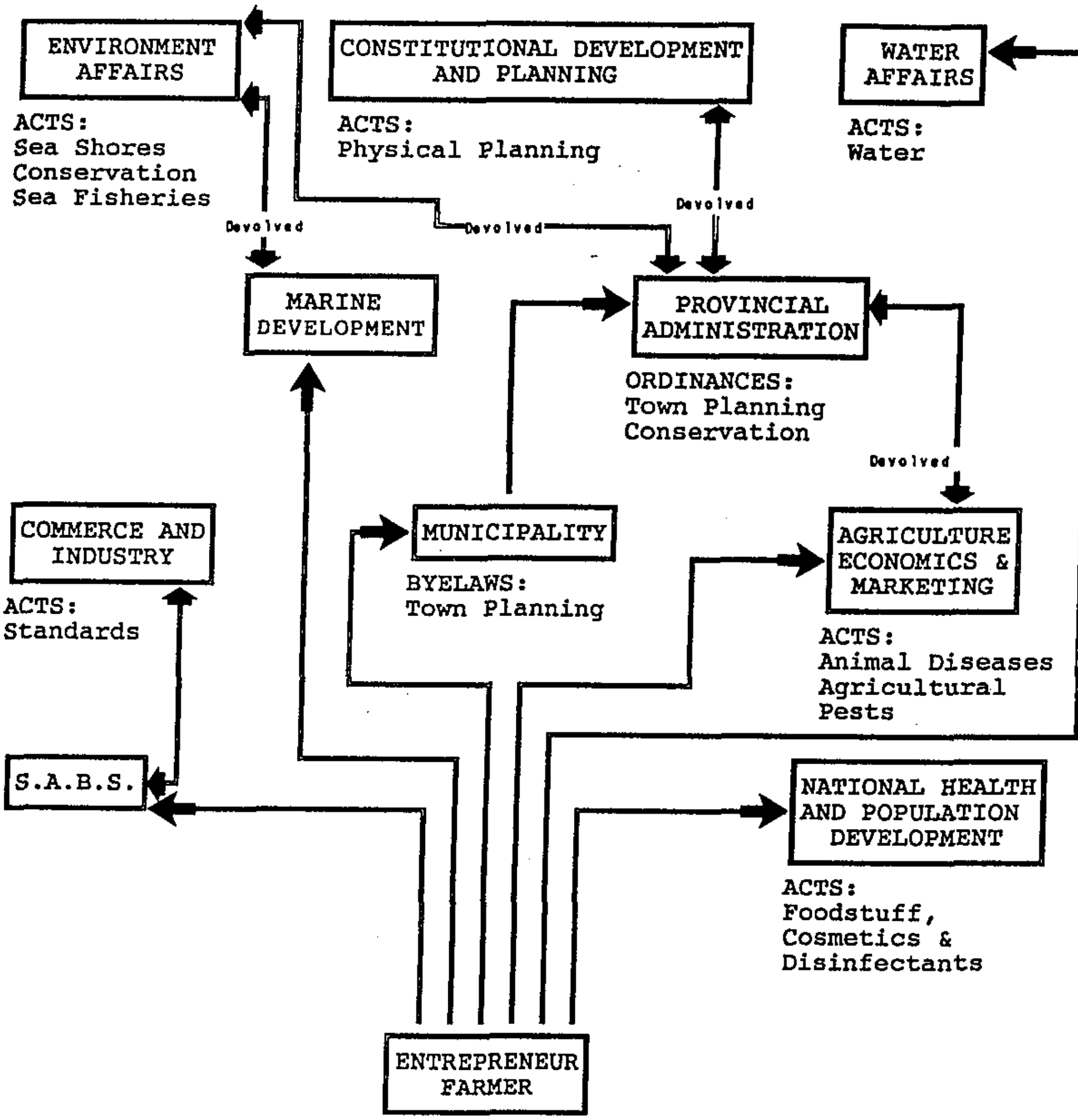

FIGURE 13.1 Diagram to show the organizations, Acts and the routes of communication to be followed by the prospective aquacultural entrepreneur.

implementation. Most entrepreneurs who wish to initiate aquaculture ventures complain not so much about the regulations as they do about the coordination between the organizations who implement them. This contribution has identified some six different regulating authorities who each have to be approached for a permit of sorts (Figure 13.1). Few of these agencies have a clear perspective of the overall implications of aquaculture development and the entrepreneur is caught up in a web of bureaucracy which is disabling rather than enabling. Pressure needs to be exerted on central Government to develop some means by which responses to permit requests can be coordinated and responded to on an interdepartmental basis. The entrepreneur can then look forward to obtaining a speedy negative or positive response to his application and have the knowledge that the response has received the correct and integrated input of all the appropriate departments.

The establishment of such a "lead agency" would go a long way towards solving this problem.

The evolution of regulations requires that there be a constant interaction between the producers or their representatives, and the regulating authorities. This implies that producers themselves have to form an active lobby system which can bring about the necessary changes. In South Africa the establishment of associations, boards and unions seems to be the only way in which regulating agencies will recognize representation and attend to the needs of the industry. At present the aquaculture industry has the Trout Farmers Association and the South African Farmers Union who actively contribute to the development and change of regulations. However, the establishment of additional associations can only be beneficial to the development of an efficient aquaculture administration system in South Africa.

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CHAPTER 14. CONCLUSIONS

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The primary goal of the workshop was to synthesize the available data on those aspects pertinent to the development of commercial sharptooth catfish culture in the southern African region. These proceedings will, however, obviously also be of benefit to organizations or individuals who wish to culture sharptooth catfish on a subsistence basis within and beyond the geographic limits of southern Africa. The intention of the workshop was not to produce a definitive guide to the culture of catfish but to produce a document which potential entrepreneurs could consult in order to determine whether to go ahead with a catfish culture project or not. It is, however, recommended very strongly that a decision to go ahead should not only be based on the contents of these proceedings, but should be taken in consultation with experts.

Several important issues were raised at the workshop. From the very start it became evident that greater cognisance should be taken of the behaviour and other aspects of the animals natural history to enhance its culturability. A good example was the suggestion of custom designed ponds for maximizing the use of space and volume although under practical fish farming conditions they may be more of an encumberance than anything else. Furthermore, the great adaptability of the catfish should be enhanced, particularly in view of its communication abilities for the improvement of food intake and the resultant effect on food conversion efficiency and the reduction of stress. In fact relatively little is understood about stress in *Clarias gariepinus*. This is probably as a consequence of its wide ranging environmental tolerances. Nevertheless, it was felt that research in this direction might be of considerable benefit to the producer as well as to the esoteric interests of the scientists.

The importance of broodstock quality on the growth of larvae and juveniles was another factor which had been largely overlooked in the past. A suggestion was made to the effect that good broodstock management, which results in a better quality yolk and therefore better quality larvae, is more important than "pampering" the larvae. Furthermore it was pointed out that good broodstock management would to a large extent negate the importance of sophisticated research on reproductive techniques. It was pointed out that the present level of success of larval and juvenile rearing in the hatchery was in the region of 10%. Despite the low survival rate the operation is still highly economical and hatchery owners are able to meet the demand for fingerlings quite comfortably. Nevertheless this low level of success was regarded by all as unacceptable. A recently completed project on the environmental requirements of larvae and early juveniles will go a long way towards improving the present situation.

An interesting discussion developed around the economic feasibility of catfish hatcheries. The background to the discussion is presented in Chapter 4. Essentially it was calculated and decided after a post-workshop get-together that it would only be economically viable for a catfish farmer to establish his own hatchery if his requirements for fingerlings exceed 500 000 per year. Personally I am also of the opinion that a prospective catfish farmer should first of all master the techniques of production pond management before attempting to also produce his own fingerlings.

It also came across strongly that a greater research effort was needed in terms of genetic selection. Whether it would be possible to select for faster growth was debated. In the end it was decided that selection should focus on the development of strains with an improved dress out percentage and product enhancement in terms of flesh colouration and texture.

Throughout the workshop the need for a government "lead agency" for the future development and growth of aquaculture in South Africa was stressed. One of the primary functions of such a lead agency would be to create a single channel through which to apply for permits to initiate an aquaculture operation. Presently there are umpteen confusing paths which a potential freshwater fish farmer has to follow prior to obtaining the necessary permits. Needless to say the present system is a veritable minefield and therefore totally inefficient and cumbersome and in fact detrimental to the development of the industry. Freshwater aquaculture at present is represented by the South African Agricultural Union but has no real home within the statutory system. It became obvious that the logical home would be the Department of Agriculture and Water Supply. At the conclusion of the workshop an embryo body "The Sharptooth Catfish Producers Association of South Africa" was formed which will be affiliated to the South African Agricultural Union. One of the aims of this body will be to seek a home for South African freshwater aquaculture, similar to the way in which the interests of Mariculture in South Africa is served by the Directorate of Marine Development. However, the Catfish Producers Association should not act alone but seek the assistance of the numerous Aquaculture Associations which already exist in the country, viz the Ornamental Fish Growers Association, the Trout Farmers Association, the Transvaal Crocodile Farmers Association and the Cape Aquaculture Society. As a first step it would seem logical if all these associations or societies were to throw their lot into a single pot and form an umbrella organization. Such a body would carry far greater weight in the endeavour to secure a statutory home for freshwater aquaculture.

One of the most important issues raised for discussion was the need for adequate financial planning. In fact good financial planning is crucial for the ultimate success of an operation. The discussion generated by the need for financial planning certainly highlighted the complexities surrounding the development of a successful aquaculture venture. Based on the discussion, the definition of aquaculture undertaken on capitalistic private enterprise principles could be rewritten as: A multi-and interdisciplinary complexity of enhanced production of aquatic organisms under controlled conditions incorporating science, business acumen, common sense and experience. It is therefore of the utmost importance that the initial planning phase of any venture be undertaken with great caution, paying heed to expert biological and financial advice and to be conservative rather than to be blinded by the possibility of making the proverbial "quick buck". It was pointed out that the prospective entrepreneur should undertake his homework properly and to make full use of available expertise on a consultancy basis. It was also shown that a considerable saving in terms of operating costs and capital can be achieved if aquaculture is tied in with other forms of agriculture.

The matter of insurance was touched upon briefly. The conclusion reached was that because of the present variable production figures the premiums for stock insurance would be of a magnitude irreconcilable with the actual

value of the stock. However, it was decided that once a high level of efficiency had been attained in the industry as a whole then the matter of insurance should be investigated by the Catfish Producers Association.

One of the problems during the artificial propagation of catfish has always been the guesswork associated with the condition of the male testes, which can only really be evaluated once the animal has been sacrificed. Some success has been achieved in the hand-stripping of semen from the male after hypophyzation. Unfortunately this technique has not yet been tested under large-scale spawning trials. It is very necessary to continue with this research, particularly if any form of genetic selection is envisioned. To a great extent the successful cryopreservation of catfish semen would already be a plus factor in any selection programme.

Apart from the above value of cryopreservation this technique could also contribute towards the enhancement of the population gene pool without having to bring in "foreign" stocks and in so doing expose the "indigenous" stock to possible new diseases or parasites, unknown to the area. The technique could possibly also be of value for the continued, highly successful hybridization of *Heterobranchus longifilis* with *Clarias gariepinus*.

The session on processing and marketing was extremely interesting. The largely theoretical nature of the contribution highlighted the fact that this has, up to now, been a much neglected area. Considering the fact that the quality of the end product will largely determine the long-term success of a catfish culture venture it is essential that more attention be given to product development and marketing. It was pointed out that the producer should guard against delivering an inferior product onto the market. It was also pointed out that "freshing out" was a cardinal prerequisite prior to the delivery of fish to the market or to processors. This requires that the fish be kept in plastic ponds with a high rate of water exchange under aeration for a minimum period of three days. During this period they should not be fed. In addition the idea was expressed that the Catfish Producers Association should largely be responsible for the initiation of research into product enhancement and marketing.

Several issues were raised at the workshop which remain unresolved. These included the legal utilization of certain chemicals for prophylaxis and antibiotics for the treatment of diseases. It has since come to light that no drugs or chemicals are registered in South Africa for use in fish. This would imply that all drugs and chemicals may only be used on prescription and the person who issued the prescription would carry full responsibility. The issue regarding the incorporation of agricultural wastes, such as chicken entrails and brewery waste, into feed has up to the time of writing not been resolved. As a source of reference, Act 36 of 1946 (ie the animal feeds and additives act of the RSA) applies to this problem. There is an urgent need to address this question as the use of agricultural wastes, as a supplement to the high priced pelleted feeds in South Africa, could significantly increase the profitability of sharptooth catfish farming throughout in the region.

Although the primary aim of the workshop was to synthesize the present state of the art of catfish culture, an attempt was also made to identify research needs. Some of these needs have already been addressed above.

In addition, the following research needs were identified: vitamin requirements of catfish larvae and juveniles; the determination of digestible energy values; the effect of temperature on production; the establishment of feeding tables; the interrelationship between stocking density and environmental conditions and disease or parasite infections; interrelationship between stocking density and stress; to investigate alternative chemicals for the treatment of protozoal and fungal infections during the fertilized egg stage and during the larval and early juvenile stages. The reasons for the latter research need was expressed because of the low tolerance of larvae and early juvenile catfish to conventional chemicals such as formalin. It was pointed out that prevention is better than cure, but in very many instances this was easier said than done.

The point was made that extreme care had to be taken to ensure that fingerlings are disease free when transporting them from one area to another, particularly between river catchments. In other species this practice has led to the translocation of several exotic parasites eg *Argulus japonicus* and *Bothriocephalus acheiloglanis*.

The present levels of production are highly encouraging and certainly augurs well for the future of catfish farming in the subcontinent. The maximum recorded yield up to the time of writing was 65 tons ha^{-1} per 10 months. Average yields vary between 20 and 45 tons ha^{-1} yr^{-1}. Presently a research programme is underway which has as its primary objective the determination of the optimal stocking density of catfish during the production grow-out phase in earthern ponds. Results so far indicate that stocking densities could possibly far exceed the present level of 100 000 fingerlings per hectare. A closer cooperation between producers and researchers was advocated.

It is hoped that the proceedings of this workshop will have made a contribution towards the future success of sharptooth catfish farming in the region. These proceedings do not in any way proclaim to be a definitive guide to the successful culture of the species. Nevertheless, we are of the opinion that there now exists a solid foundation upon which to develop the farming of *Clarias gariepinus* in the subcontinent. In the relevant chapters on hatchery procedures, production and financial planning caution has been the watchword. Consequently we hope that the development of the industry will go ahead in an orderly manner without overhasty decisions. There are many factors which have to be considered before a decision is made to commit funds for the development of a catfish farm. These include: the environmental requirements of the animal; the climate of the particular regions; water requirements and availability;

the availability and cost of management expertise, the cost of feeds, the availability of alternate feeds as well as the differential capital cost, determined largely by the price of land, and the marketability of the product at a price which will yield a satisfactory return on investment. All these factors need to be considered and incorporated into a cost analysis model to determine the feasibility of the operation prior to it initiation.

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