

A REVIEW OF RECENT ADVANCES IN COMMERCIAL  
TILAPIA CULTURE

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ABSTRACT

The paper introduces the tilapias as important culture fishes; their classification, breeding habits and general ecology. The versatility and plasticity of their reproduction and growth are major advantages as well as draw backs in their use as culture species. The culture of tilapias in ponds, cages, pens and raceways are described and a comparison of extensive and intensive cultivation is made.

The major factors in commercial cultivation of tilapias such as feeds, hatchery/fry production and disease control are discussed. Recommendation is made for the consideration of tilapia as the equivalent of the common carp in tropical African fish culture in either monoculture or in polyculture with other fish species.

INTRODUCTION

The tilapias are particularly well-suited to aquaculture in that they are principally primary consumers or detritivores, they are hardy and have wide tolerance limits to most potentially limiting environmental variables such as temperature and oxygen and they will spawn readily in ponds to produce large numbers of fry for stocking.

Indeed tilapias are well-known - even notorious in fish culture circles for the facility with which they reproduce. Moreover, it is the plasticity of their reproductive, growth and developmental processes which are the main advantages and also major draw-backs in the use of tilapias for culture; at the same time these processes also hold the key to the future of tilapia farming through selective breeding to true domestication.

## BREEDING METHODS AND CLASSIFICATION:

Tilapias are not particularly fecund fish but the relatively large egg and yolk supply combined with a high degree of parental care ensures a high survival rate amongst the fry.

Parental care, however, comes in a number of forms which have recently been reviewed (Ruwet et al 1976; Phillipart and Ruwet 1982) in the light of recent suggestions regarding the systematics of the group (Trewavas 1983).

There are three approaches to parental care in tilapias which are important for their culture.

- (i) Guarders: Guarders or substratum spawners where the male builds a nest of several holes within a vigorously guarded territory. A female is attracted; the eggs are laid and fertilized in the holes and then guarded throughout the incubation period and early development. Monogamy is practised by the guarders.
- (ii) Mouth Brooders: The male builds a saucer-shaped nest, within a spawning arena, to which a female is attracted. She lays a batch of eggs which are promptly fertilized by the male and then taken into an oral broodpouch in the mouth of the female. The female may then deposit a second batch of eggs to a neighbouring male in the spawning arena. There is, thus, no pair bond, as in the 'guarders', and both polyandry and polygamy can occur. Thus the eggs in the mouth of the female could have been fertilised by several males.

## PATERNAL OR BIPARENTAL BROODERS:

It is either the male or either sex which mouth-broods the eggs in this group. This is very similar to maternal brooding but these types do not adopt the arena spawning. Consequently, although mating and fertilization still only take a short time, mating appears to be monogamous.

The evolutionary implications of these three mechanisms are that the possible genetic variation resulting from the promiscuous arena spawning maternal brooders is potentially much greater than that of either the guarders or the paternal/bi-parental brooders. It may, therefore, be no accident that of the ninety (90) or so species of tilapia recognised, thirty (30) are guarders, eighteen (18) are paternal/bi-parental brooders and forty-two (42) are maternal brooders. Of the three methods guarding is the most primitive.

## ZOOGEOGRAPHIC DISTRIBUTION OF TILAPIAS:

The guarders are now referred to as Tilapia species (Trewavas 1973) while the maternal brooders are Oreochromis species; and biparental brooders are classified as Sarotherodon species (Trewavas 1982 ; 1983). These generally fall into relatively uniform geographic groups in that Tilapia species are confined to West Africa with the exceptions of T. zillii and T. rendalli which have extended their ranges into central and East Africa; whilst Oreochromis is distributed over central and East Africa and one or two rivers of the Levant. The Sarotherodon species, apart from the more widely distributed S. galilaeus are restricted again to West Africa.

Distribution of a few species of tilapias is now widespread in the tropical world due to their introduction for culture (Welcomme 1981, Balayut 1983).

## NATURAL HABITAT OF TILAPIAS AND THEIR ADAPTABILITY

Although tilapias originated in rivers they are preadapted to lakes where seasonal variations in the tropics are limited. Tilapias contribute a high proportion of the ichthyomass in man-made lakes such as 35% in Lake Kariba, 57% in Lake Volta (Petr 1967) compared with only 4% in the Rufiji River in Tanzania (Payne and Collinson 1981) and 3% in the Zambesi (Petr 1987). The higher phytoplankton production in lakes must be a contributory factor to the success of microphagous and planktivorous Oreochromis and Sarotherodon species. Never the less, the availability of nesting sites is critical hence in the early years of post impoundment of Lake Kainji tilapias contribution to the fish catch and biomass was low because of the large seasonal draw down which coincided with the spawning seasons of the S. galilaeus and O. niloticus in the Lake, (Ita, 1973). However, it seems that the tilapias in Lake Kainji have adapted to the hydrology of the Lake as rotenone sample estimates in later years in the littoral areas of Lake Kainji showed the tilapias contributing 43% of the ichthyomas (Ita, 1984, Sagua, unpubl.).

The tilapias show great variability and adaptability in their growth and reproductive strategies within their normal environment. Under adverse conditions they can spawn at very small sizes. For example O. niloticus in Lake Albert spawn at 28cm while in isolated lagoons of Bahuka they begin at 10cm - a real bane of fish culture. They also can spawn at a younger age (Iles 1972). Precocious spawning is most valuable in rivers which are prone to leaving seasonal pools as the flood recedes as was observed for S. galilaeus in the River Sokoto (Iles and Holden 1969). Such habit is undesirable in tilapia culture because this can lead to rapid over population and reduced growth of the cultured fish.

In tilapia the smaller fish produce proportionally more eggs than the larger fish - a direct consequence of the unusual relationship between fecundity (F) and body length (L)

whereby  $F = @ L^2$  instead of the usual  $F = @ L^3$  (@ = constant) (Babiker and Ibrahim 1979; Welcomme 1967).

It means that it may be more efficient to keep smaller rather than larger fish as brood stock in contrast to most cultured fishes.

#### COMMERCIAL CULTURE OF TILAPIA

Selection of Tilapia Species for Culture: For commercially successful culture of tilapia the selection of suitable species for cultivation is of paramount importance. The cultivation of tilapia in Africa has been largely based on specimens taken from the wild. There is reason to believe that considerable inbreeding and inter-specific breeding has led to a variety of progeny which are hybrid species in our waters. Selective breeding programme for genetic improvement and experimental screening of the productive capability of different breeds needs to be embarked upon in Africa. At the present the potentials of the tilapia species in Africa are not tested and research on this is taking place mainly outside Africa (e.g. USA; Stirling University, UK).

A red tilapia has been bred in Florida USA, from a cross of O. mossambius and O. niloticus. It has a pink rather than black peritoneum giving it a delightful pinkish colour. It has a high gale value and preferred to the darker tilapia.

In Israel an all male hybrid has been obtained from a cross of male O. aureus and female O. niloticus. The hybrid is however fertile and therefore its commercial cultivation on large scale must depend on a hatchery that will continuously supply hybrid seed. For a successful hybrid production the specific identify of the two species must not be in doubt. This is why there is urgent need to determine and preserve pure genetic stocks of our tilapias a basis of any genetic improvement work. At the moment the techniques for such identification involve electrophoretic methods combined with detailed taxonomy, since morphological separation of some of the mixed strains and species is very difficult.

Some desirable characteristics to breed for include, fast growth rate, large adult size, efficient food conversion ratio, ease of reproduction in hatcheries, adaptability to a range of environment e.g. brackish and freshwater.

Development of monosex hybrids with suitable growth qualities from hatcheries is likely to become important.

On the whole the Oreochromis species are favoured as species for commercial culture.

#### HATCHERY TECHNIQUES FOR TILAPIA CULTURE

Cage Hatcheries: The idea of tilapia hatchery in cages came from the use of hapas. Applying the arena spawning behavioural nature of Oreochromis sp. the cage is designed so as to separate the breeders from the fry produced. An inner coarse net separates the brood fish from the fry in the patterns shown in the figures (1) or (2). The fry are harvested by means of a scoop net.

Size of cage may be 100m<sup>3</sup> or less with depth of 0.5m. breeder stocking density is 20/m<sup>3</sup>. Sex ratio of breeders is 3-7 females : 1 male. Fry production rate (4mm) average 650 fry/m<sup>2</sup>/month but over 1000 fry/m<sup>2</sup>/month is possible. Spawning frequency can be improved by increasing feeding intensity and quality of food.

#### Problem

Clogging of fine mesh net with silt, algae. Floating objects e.g. aquatic weeds.

Tank hatcheries: Tilapia tank hatcheries are best made of circular shape from cement blocks, poured concrete, corrugated iron or steel and fibre glass. The size of tank ranges from 1m to 10m or more in diameter depending on the quantity of fry needed. Depth of tank is usually about 1.5m, but if greater than 1.5m then for cement block tanks extra reinforcement is necessary.

In iron or steel tanks the inner walls need protective lining with plastic or butyl liner. Steel and fibre tanks though more expensive are very durable (can last 20 - 40 years) and can be moved to a new location unlike concrete or cement block tanks which are cheaper but immovable and have higher maintenance costs and shorter (5 - 10 years) life span.

Construction of tanks should provide for an arena for spawning separated from an outer ring where the fry collect. The figure (3) is an example of a concrete tank in use at the Boabab Fish Farm in Mombassa, Kenya where a viable tilapia culture using raceways for production is profitably operated. Costs estimates of 8m diameter fibre glass tank is £900.00, while for steel £2800 and corrugated iron £1500 in the U.K. in 1985.

Advantages of tank hatcheries over cage/hapa and pond culture are ease of control of water quality, feed and the number of fry. It is also easier to harvest the fry and to maintain a pure brood stock which is essential in genetic improvement work.

In small indoor tank hatcheries use of recycled water aerated and filtered through biological filters enables a high efficiency of fry production in a minimum space. A constant head of water is maintained in the rearing plastic or fibre glass tanks by means of a stand-pipe; the fry is protected by an outer pipe from being flushed away.

### Problems

Sedimentation of tanks and Ammonia pollution. Velocity of water needed to maintain self cleaning of tanks (7-8 body lengths/sec for small fish or 4-5 body lengths/sec for larger fish) can be withstood well by tilapia. Rearing tanks should not have depth lower than 0.7m as shape of the fish is affected at lower water depth.

### Pond Hatchery

Tilapia can breed easily in a normal fish breeding pond where females and males are kept. The ratio of females to males should be about 5:1. It is easier to collect fry if one end of the pond is shallow and the arena area is provided as shown in the cross section drawing shown (Fig. 4).

Table 1 - Fry production rates from various methods and authors

<u>Ponds</u>	10 fry/m <sup>2</sup> /month	(Rothbard et al 1982)
	Fingerlings 4-8/m <sup>2</sup> /month	Coche, 1982)
<u>Hapa (Cages)</u>	200 fry/m <sup>2</sup> /month	(Guerrero & Garcia, 1983)
<u>Tanks</u>	688 fry/m <sup>2</sup> /month	(Snow et al, 1983)
	1024 fry/m <sup>2</sup> /month	(Coche, 1982)
	1688 fry/m <sup>2</sup> /month	(Uchida & King, 1962)
<u>Tank (Hapa)</u>	3000 fry/m <sup>2</sup> /month	(McAndrews (Unpubl.))

#### Artificial Incubation of Tilapia Eggs

Fertilized eggs from known parents are removed from the brood pouch of the female and incubated in a container with water swirling around enough to keep the eggs rolling up and down. Optimum water temperature for incubation is 28°C.

High quality fry are produced through artificial incubation. Compared to parental incubation the artificial incubated eggs released fry in 12-16 days while the wild stock brooding the eggs released in 13-21 days. The earlier released fry have a head start growth advantage over the late released fry. The growth difference observed by Kahn (pers. comm.) in Stirling University for *O. mossambicus* ranged from 50% to 120%. Water quality must be very good especially with regards to eliminating ammonia and maintaining a pH of 6-7 in the incubation tanks.

Artificial incubation is very useful in genetic improvement studies where fry of uniform size and age are required for experiments.

#### Improving Quality of Fry Production

##### Sex-Reversed all-Male Fingerlings

It is essential to obtain fry of a uniform size and age for application of hormone treatment to obtain sex reversed all-male fingerlings.

To obtain these sex reversed fingerlings feed the fry on food pellets to which MT (17 - & methyltestosterone) a male steroid hormone has been added at 40 ppm. This is obtained by addition of 16 ml of a stock solution of 2.5 mg/ml in Ethan 1 of MT to 1 kg of the feed. The size of pellets to feed tilapia fry should be about 1000 microns. The fry must be fed the hormone treated food within the first 10 days of life until about 40 days. There is evidence that hormone treated fry have a higher weight gain than controls over 40 days.

Also the hormone is completely eliminated from the fish within 200 to 300 hours after cessation of feeding with the hormone food.

MT is supplied by Sigma Chemical Co. Missouri, USA for about \$10.00 per 10 gm bottle.

#### Tilapia Feeds and Feeding

In nature Oreochromis spp. and Sarotherodon spp. are mainly omnivorous as adults while the fry feed on zooplankton or phytoplankton. S. galilaeus feeds exclusively on phytoplankton. O. niloticus feed predominantly on phytoplankton and can utilise blue-green algae. O. spirulus is an omnivorous grazer. O. mossambicus feeds mainly on plankton, vegetation and bottom algae.

The Tilapia spp e.g. T. melanopleura and T. zillii are herbivores with preference for higher plants and are used for weed control.

T. rendalli adults feed exclusively on higher plants while juveniles take zooplankton and phytoplankton (Jauncey and Ross, 1982).

Clearly an understanding of the natural feeding habits and diets of tilapia can be used in their culture to prepare nutritionally balanced diets for intensive culture systems or for boosting zooplankton/phytoplankton production in extensive culture systems.

#### Nutrient Requirements of Tilapias

Table 2 Summary of the major nutrient requirements of tilapia (From Jauncey and Ross, 1982)

Nutrient	First feeding to 0.5g	0.5-10g	10-35g	35g to market size	Brood-stock
Crude protein	50%	35-40%	30-35%	25-30%	30%
Crude lipid	10%	10%	6-10%	6%	8%
Digestible carbohydrate	25%	25%	25%	25%	25%
Fibre	8%	8%	8-10%	8-10%	8-10%

From the above data carbohydrate and fibre requirements remain fairly constant while protein and lipid requirements are higher in the smaller fishes.



## Vitamin/Minerals

The feed should also contain vitamin and mineral supplements as recommended in Jauncey and Ross (1982).

## Feed Formulation for Tilapia Feeds

Feed formulation is the method of combination of raw materials available to satisfy the pre-established nutrient requirements of the cultured fish. It should be noted that the fact that a nutrient is chemically present in a given feedstuff does not necessarily mean that it is biologically available. In formulating feed we need to balance protein level, check energy level and the levels of essential amino acids and essential fatty acids.

The principle of "least cost", "best buy" is applicable here, but above all raw materials locally available should be used as much as possible.

### Example:

#### Protein sources

Cotton seed meal (54%) and groundnut meal (44%)

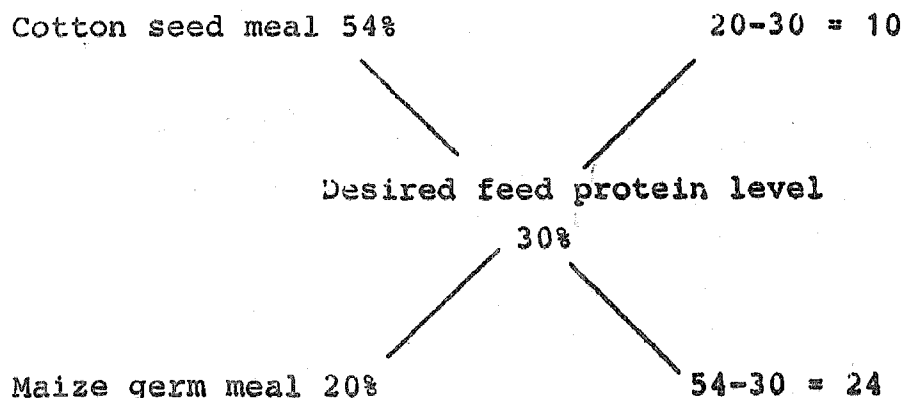
protein content.

#### Energy Sources

Rice bran or polishings contains 2700 kcal DE/kg.

Maize contains 4300 kcal DE/kg.

Supposing it is desired to formulate a 30% protein tilapia feed from cotton seed meal (54% protein) and maize germ meal (20% protein) a square is constructed thus:



The protein level of feed is subtracted from that of each feedstuff and the answers are added, disregarding positive or negative signs (i.e.  $10 + 24 = 34$ ).

To obtain 30% protein tilapia feed we need:

$$\frac{10}{34} \times 100 = 29.41\% \text{ of cotton seed meal}$$

and  $\frac{24}{34} \times 100 = 70.59\%$  of maize germ meal

By similar procedure other components can be calculated .

### Linear Programming

The best method of diet formulation is to use purpose written computer programme. The computer works out the complete analysis and costs of the available feedstuffs and the required nutrient profile of the feed. Programmes such as these can be purchased.

### Parasites and diseases of Tilapia

In extensive and semi-intensive tilapia cultures diseases have not been a problem, but under intensive cultivation with high stocking density and intensive feeding diseases could become a problem.

### Parasites groups seen on tilapia

These include protozoans - flagellates, ciliates and sporozoans e.g. Myxosoma cerebralis causing whirling disease. Metazoans include helminths, - monogenetic and digenetic flukes, Nematodes and leeches.

Among the crustacean parasites are Branchiurans, Copepods (e.g. Argulus, Ergasilus, Lerneae) and isopods the later are increasingly becoming important.

Effect of parasites include:

- reduction in growth rate
- poor food conversion efficiency
- increased cost in treatment/control
- reduced carcas value
- castration and pre-spawning mortality.

## Examples

White spot disease "ich" ichthyopontarus - a ciliate. This is an important killer of hatchery fry controlled by liming.

Ciehladogyrus - attached to gills of tilapia causing damage but does not kill the fish.

Gyrodactylus - found on skin of fish and can kill tilapia rapidly.

## Bacterial diseases

- (i) Flexibacter columnaris (saddle back) - diseases occur where a damage or lesion occurs to the skin at temperatures above 30°C. Control by reducing water temperature below 30°C.
- (ii) Flexibacter psychrophila - This loves cold water and affects the ventral fins or tail of the fish.
- (iii) Flexibacter spp - Causes gill rot disease in young small tilapia. Treatment by washing the affected gills with detergent.
- (iv) Enterobacterial - Diseases caused by Yerisiwa muckerii, Edwardsiella tarda. These cause haemorrhages killing fish and causing an awful nasty foul smell when the fish is cut open even when still alive.
- (v) Treatment - Drain pond and lime and let the pond dry before refilling.

Proteus rettgari - introduced to fish pond through chicken manure. Caused loss of over 200 tonnes of silver carp in Israel.

Aeromonas hydrophila - commonly found in tilapia ponds. Attacks of this organisms comes after the fish has been weakened by a virus attack. The abdomen is swollen and red spots on the mouth.

Control - drain the pond and lime it and let it dry up.

Streptococcus faecalis - associated with poor handling and human faeces or manure pollution.

Botulism - is very common in tilapia caused by Clostridium botulinum which is in the mud of the pond.

## Virus caused diseases

Lymphocystis - an irodovirus.

Use of antibiotics not recommended. Strict quarantine laws should be enacted, and enforced to prevent importation of fish pests and diseases.

#### Recommendations on Tilapia

The tilapias are the best studied tropical culturable fishes and they have the best prospect of becoming the equivalent of the carp in Africa.

To achieve success it is recommended that pure genetic resources of the various tilapia species be kept in genetic banks in Africa from which breeding work can be done to develop highly suitable strains as parent stocks for hatchery work. The research Institutes and universities should do this.

The future of tilapia in fish culture depends on efficient hatcheries to produce good quality fry and fingerlings plus a good feed base for intensive cultures.

The high proliferation of tilapia could also be utilised to produce small fishes for fish meal production.

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SUMMARY OF CAGE AND PEN CULTURE OF TILAPIAS

(a) Comparison of Cage and Pen Cultures

TYPE OF ENCLOSURE	SIZE (M <sup>2</sup> )	SHAPE	CAPITAL COSTS	TYPE OF CULTURE	COMMENTS
FIXED CAGE	1-10 <sup>2</sup>	Square	LOW	EXT/SEMI-INT/ INT	Production flexible, however not suitable for exposed or deep water site ( 8m).
FLOATING CAGE	1-10 <sup>3</sup>	SQUARE/CIRC/ RECTANGULAR	MEDIUM	EXT/SEMI-INT/ INT	Production flexible Comparatively strong
PEN	10 <sup>3</sup> -10 <sup>5</sup>	VARIABLE	MEDIUM- HIGH	EXT/SEMI-INT/ INT	Inflexible production However not suitable for deep water sites ( 8m) Hard substrates is a problem. Good growth

(b) Comparison of extensive, semi - intensive and intensive cultures

METHODS OF CULTURE	STOCKING DENSITY (M <sup>3</sup> )	FEED	SITE	PRODUCTION kg/m <sup>3</sup> /month	COMMENTS
EXTENSIVE	4-10	natural	lentic	Less than 2	Experiences suggest difficulty to maintain production due to over-exploitation of site
SEMI-INTENSIVE	10-50 +	less protein (10%) plant & agricultural by products	lentic/lotics	Less than 4	Most popular method Addition of some food usually increase production unless phytoplankton bloom conditions prevail
INTENSIVE	50-200 +	high protein ( 20%) artisanal or commercial	lentic	5 - 15	Rare. Advisable where growing season is short or where water resources scarce. Need high retail price to make profit