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The importance of tilapias (Cichlidae) for tropical aquaculture

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Abstract
In warm water aquaculture species of the family Cichlidae, commonly known as tilapias, are produced in many tropical and subtropical countries and contribute considerably to the energy and protein supply of people in rural regions. Within 10 years (1988 to 1997) world aquaculture production of tilapias and other cichlids increased from 308 234 t to 945 723 t, cultured in a wide range of systems from small inland farm ponds to brackish water enclosures along the coastline. Most important tilapia species is the Nile tilapia (*Oreochromis niloticus*). Total production of this species amounted to 741 867 t in 1997. Main producers are China, Thailand, the Philippines, Egypt and Indonesia. To avoid overpopulation in ponds by uncontrolled reproduction which is a serious problem in pond culture monosex tilapia hybrids can be used. Tilapias are well suited for polyculture with other fish species and for integrated aquaculture in the tropics.

Keywords: aquaculture, Cichlidae, tilapias, *Oreochromis niloticus*

Tilapias, belonging to the fish family Cichlidae, tribus Tilapiini, comprise about 70 to 100 species. According to Trewavas (1982) they are divided into four genera. However, also other classifications were proposed (Fishelson and Yaron, 1983). The differentiation of the mentioned genera is based mainly on their breeding behaviour. The genus *Tilapia* comprehends substrate spawners which build nests on the bottom. Species of the genus *Sarotherodon* are paternal or biparental mouth-brooders and that of the genus *Oreochromis* maternal mouth-brooders (Table 1).

Table 1. Genera of the tribus Tilapiinae (Trewavas,1982)

Genus	Breeding behaviour
Tilapia	Substrate breeder
Sarotherodon	Paternal or biparental mouth breeder
Oreochromis	Maternal mouth breeder
Danakilia	unknown

There are also substantial differences in the feeding. Species of the genus *Tilapia* feed on macrophytes. *Sarotherodon* and *Oreochromis* species are characterized by the existence of long, thin, closely spaced gill-rakers which enable the fish to feed on small phytoplankton and even on detritus. Important feed components are also bacteria, zooplankton and other invertebrates. Usage of blue-green algae (Cyanophyta) was demonstrated in some species (Moriarty and Moriarty, 1973).

Tilapias can tolerate water temperatures between 6.5-11 ^{0} C and 40-44 ^{0} C, for reproduction a minimum temperature of 20 ^{0} C is necessary. Optimum temperature may be 25-30 ^{0} C. The fish withstand low oxygen levels (< 2.5-3 mg/l) up to 10 % of satiation for several hours. Some species are euryhaline (e.g. *Oreochromis mossambicus*) and accept salinities to more than 3 %, so can be cultured also in brackish waters (Balarin and Hatton, 1979; Philippart and Ruwet, 1982).

Tilapias are endemic to Africa. Since 1939/40 they are found in Java (*Oreochromis mossambicus*, likely introduced by aquarists) and spread very rapidly throughout the island. Today tilapia species live in many tropical and subtropical countries predominantly of the African and Asian, but also of the South American continents and belong to the most important species of warm water aquaculture all over the world.

In 1984 only 189 113 t of tilapias and other cichlids were produced worldwide in aquaculture. Within 10 years (1988 to 1997) world aquaculture production of tilapias and other cichlids increased from 308 234 t to 945 723 t, cultured in a wide range of systems from small inland farm ponds to brackish water enclosures along the coastline (Table 2).

Table 2. World aquaculture production of tilapias and other cichlids 1988-1997 (FAO, 1999b)

Year	Aquaculture production (t)
1988	308 234
1989	362 394
1990	396 366
1991	413 598
1992	501 620
1993	560 964
1994	603 683
1995	711 004
1996	817 527
1997	945 723

The by far most important species is the Nile tilapia, *Oreochromis niloticus*. Total production of this species amounted to 741 867 t in 1997. Main producers are China, Thailand, the Philippines, Egypt and Indonesia (Table 3). The second most important species is the Mozambique tilapia, *O. mossambicus* which is mainly raised in Indonesia. The FAO statistics reveal a third group of unspecified tilapias. Together with the just mentioned two species they make nearly 99 % of all cultured tilapias.

Table 3. Aquaculture production of *Oreochromis niloticus, O. mossambicus* and unspecified tilapias (tilapia nei) in selected countries and world totals in 1997 (FAO, 1999b)

Country	Aquaculture production (t)
Oreochromis niloticus	
China	485 459
Thailand	120 102
Philippines	78 491
Egypt	30 416
Indonesia	29 000
World total	741 867
Oreochromis mossambicus	
Indonesia	54 500
World total	61 188
Tilapia nei	
Taiwan	42 158
Colombia	14 554
Brazil	13 660
Philppines	13 340
Mexico	8 318
World total	127 055

The enormous development of the Chinese production of *O. niloticus* during the period 1980 to 1995 is shown in Table 4.

Table 4. Aquaculture production of *Oreochromis niloticus* in China 1980-1995 (Wang, 1993; completed)

Year	Aquaculture production (1000 t)
1980	9.0
1985	23.8
1990	106.1
1995	314.9

In 1997 the Nile tilapia was within the top twelve species of world cultured aquatic production, ranked by volume (Table 5). In this time tilapia accounted for about 5 % of all cultured finfish; according to the opinion of the FAO (1999a) this share is very likely to increase significantly over the next decade.

Table 5. The top twelve species of world aquaculture production in 1997, ranked by quantity (FAO, 1999b)

Common name	Latin name	Production (mill. t)
Kelp	*Laminaria japonica*	4.40
Silver carp	*Hypophthalmichthys molitrix*	3.15
Pacific cupped oyster	*Crassostrea gigas*	2.97
Grass carp	*Ctenopharyngodon idellus*	2.66
Common carp	*Cyprinus carpio*	2.24
Bighead carp	*Aristichthys nobilis*	1.55
Japanese carpet shell	*Ruditapes philippinarum*	1.28
Yesso scallop	*Pecten yessoensis*	1.26
Crucian carp	*Carassius carassius*	0.86
Laver	*Porphyra tenera*	0.86
Nile tilapia	*Oreochromis niloticus*	0.74
Atlantic salmon	*Salmo salar*	0.64

Other important tilapia species for aquaculture are the blue tilapia (*O. aureus*), the longfin tilapia (*O. macrochir*), the three spotted tilapia (*O. andersonii*), *O. melanotheron*, *O. hornorum*, *Tilapia rendalli* (= *melanopleura*) and *T. zillii*. However, in many cases no pure species but often hybrids are raised because natural cross-breeding frequently occurs. This situation has become a matter of concern. Largely uncontrolled introductions and transfers of different tilapiine species of various origin all over the world for decades have led to activities for a better knowledge and documentation of the genetic diversity of these species together with attempts for the conservation and sustainable use of these resources. Today laboratory manuals of methods for tilapia species identification exist (Falk et al., 1996) and modern, public access information technology is being used for the documentation of this genetic biodiversity (Froese and Pauly, 1998).

Mostly tilapias are cultured in earthen ponds of different size, varying between few square meters and several hectares. Cage culture is also usual and in some Asian countries tilapia production is carried out in rice fields. In the USA tilapias are produced preferably in intensive recirculation systems using indoor tanks.

Tilapias may be raised in monoculture but polyculture is also a common practice in many areas. Integrated animal and fish farming systems are of considerable importance especially in several Asian and African countries.

On the premises of favourable temperature conditions *O. niloticus* is a very fast growing species and genetic work has led to further progress which should help to increase production of this species substantially in the future. As in other tilapia species males grow much better than females and attain a larger size. Research on genetic improvement conducted over the last decade in the frame of the GIFT-programme (Genetically Improved Farmed Tilapia) led within a few generations to a strain superior in growth and survival as compared to local strains of the Philippines, where the first part of this research had been performed. The yield potential was then compared to other strains existing under diverse environments in different

Asian countries like Bangladesh, China, Indonesia, Thailand and Vietnam. Here again the superiority of the GIFT-strain could be demonstrated (Dey and Eknath, 1997). A further substantial increase in the production of tilapias seems possible by combining such strains with sex inversion techniques.

Maturity may be attained by many tilapia species at good nutritional conditions and high water temperatures as early as at an age of three months and the fish can breed in successive cycles at 4-6 weeks intervalls. This leads to continuous fry production and overpopulation and results in retarded growth (stunting). Therefore the prevention of uncontrolled spawning and overpopulation is very important in tilapia culture in order to enable a successful management of tilapia ponds and to obtain marketable fish of desired weight in a short time.

The difficulties can be overcome in different ways. One method is to sort out only males for producing fish of marketable size by visual examination of the genital papillae. This is possible at the earliest with fingerlings weighing 20-50 g and errors in sorting are not to avoid. However, even few females can cause a lot of undesired fry.

Mono-sex male tilapia stocks also may be achieved by adding methyltestosterone or ethynyltestosterone to the feed of the fry for about 3-8 weeks (10-60 mg/kg fish). Before making use of this technique in general one has to make quite sure that no residues of the hormone are left behind in the marketable fish. It should be noted that the use of sex steroids is prohibited in the European Community (Council Directive 96/22/EG).

All-male progeny in tilapia is available by inter-specific hybridizations, too. Hickling (1960) was successful by crossing *O. mossambicus* females with *O. hornorum* males. Later on other crossings became known which equally produced 100 % or nearly 100 % male offspring (Table 6). A fast growing all-male hybrid is also the so-called red tilapia which is characterized by a redddish-orange colour and is appreciated in the Asian market in preference to the normally coloured fish. It may be originated from hybridizations between *O. mossambicus*, *O. hornorum*, *O. niloticus* and *O. aureus* (Galman and Avatlion, 1983). However, hybridizations require selected pure lines and do not always result in 100 % male offspring.

Table 6. Interspecific all-male or predominantly male hybrids in tilapia

Hybrids (Ε x Γ)	Authors
O. mossambicus x *O. hornorum*	Hickling (1980)
O. niloticus x *O. hornorum*	Pruginin & Kanyike (1965)
O. niloticus x *O. aureus*	Fishelson (1962)
O. niloticus x *O. variabilis*	Pruginin (1967)
O. spilurus niger x *O. hornorum*	Pruginin (1967)
O. vulcani x *O. hornorum*	Pruginin (1967)
O. vulcani x *O. aureus*	Pruginin (1967)
O. niloticus x *O. macrochir*	Lessent (1968)
O. macrochir x *O. mossambicus*	Majundar & McAndrew (1983)

According to the investigations of Kronert (1987) and Oldorf (1987) the success of a selection of late maturing tilapia (*O. niloticus*) can be seen as very promising. A decisive breeding advancement can be determined within a few generations due to the high variabilities of the selection criteria, the height of the heritabilities and the possible selection intensity.

The use of triploid tilapia may be also a possibility for increased efficiency in tilapia pond culture. As mentioned by Brämick (1995) simplified methods for generating high amounts of triploid tilapia are, however, necessary for application of triploidization techniques to commercial fish culture.

Another method to reduce tilapia overpopulation on the strength of uncontrolled spawning is the additional stocking of certain numbers of predatory fish. Frequently used predator species are summarized in Table 7. Surely, it is not easy to find the appropriate tilapia-to-predator ratio.

Table 7. Frequently used predatory fish to control tilapia overproduction in ponds (Guerrero, 1982; Brämick, 1995)

Predator	Stocking ratio (predator : tilapia)	Authors
Cichla ocellaris	1 : 15	Lovshin (1975)
Cichlasoma managuense	1 : 4 - 1 : 8	Dunseth & Bayne (1978)
Clarias spec.	1 : 10 - 1 : 20	Meecham (1975)
Elops hawaiiensis	1 : 10 - 1 : 20	Fortes (1979)
Hemichromis fasciatus	1 : 48	Bardach et al. (1972)
Lates niloticus	1 : 20 - 1 : 84	Planquette (1974)
Megalops cyprinoides	1 : 10	Fortes (1979)
Micropterus salmoides	no data	Swingle (1960)

For obtaining the desired marketable size of tilapia in a short time pond fertilization and feeding are essential steps. Since most of the cultured species are to be considered as omnivorous fish a great variety of feedstuffs including considerable amounts of plant materials can be applied. Frequently feeds are mixed in the farms using locally available ingredients (on-farm feeds). Thus in tropical countries the application of substances as e.g. rice bran, copra meal, cotton seed oil cake, wheat middlings, soybean cake or meal and fish meal is usual (New et al., 1993; Pillay, 1995).

Polyculture with other fish can contribute to better feed utilization and to improvement in the chemical regime of ponds. Recommended polyculture species are e.g. common carp (*Cyprinus carpio*), mullet (*Mugil cephalus*), silver carp (*Hypophthalmichthys molitrix*) in Israel, tambaqui (*Colossoma macropomum*) in Brazil (Sarig, 1983; Lovshin, 1982).

Under advantageous conditions two or three crops per year in raising marketable tilapia are attainable in the tropics. According to Lovshin (1982) annual productions of 5 to 12 t per ha (fish weight up to 500 g) are possible. With high stocking densities, intensive feeding and aeration (at least during night hours) production of up to 25 t/ha per annum has been obtained (Hepher and Pruginin, 1982).

The edible portion (musculature and skin without scales) of male and female *O. mossambicus* amounts to about 50 % (Steffens and Rennert, 1985). It contains 19-20 % crude protein and 4 % crude fat (Table 8). Differences between sexes are insignificant. The white flesh is well accepted by most of the people in tropical and subtropical areas and is a valuable source of both energy and protein.

Table 8. Proximate analysis (% of fresh weight) of the edible part of male and female *O. mossambicus* (Steffens and Rennert, 1985)

Sex	Γ	E
Weight (g)	458	175
Dry matter	24.7	25.6
Crude protein	19.0	20.0
Crude fat	4.4	4.2
Ash	1.3	1.4

As was explained by FAO (1999a) tilapias seem to be assured a future owing to their specific production characteristics („water chicken"). They are common in Africa, Asia, Latin America and the Caribbean and can be produced by most developing countries with tropical and semi-tropical climates, without reliance on imported inputs. Tilapias can be farmed in various aquatic environments and there are several different culture technologies available for these species, some of which permit farmers to produce tilapia at a relatively low cost. Selective breeding is already showing positive results. As long as precautions are taken to preserve biological diversity where possible, there need not be significant environmental externalities or costs associated with the culture of tilapia.

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