Survival of a Deformed "Miracle Fish" *Oreochromis Niloticus* in an Intensive Water Recirculating System

Thomas T. George

The "miracle fish" *Oreochromis niloticus* is the world's most important warmwater cultured food fish, and is farmed under both extensive conditions and in super-intensive recirculating systems. This is possible because the fish is hardy and tolerates water conditions with a wide range of physical and chemical characteristics. It can survive even when it is deformed. This paper reports on how an *Oreochromis niloticus* developed its dorsal and anal fins to perform the action of an atrophied caudal fin.

Introduction

The "miracle fish" *Oreochromis niloticus* is one of 77 tilapia species that belong to the Family Cichlidae of the Tribe Tilapiini.[1,2] It originated in the African continent and evolved in the River Nile.[3,4] It has colonized widely different habitats due to its efficient grazing habits, relatively low position on the aquatic food web, rapid growth rates, and large sizes at first reproduction. Also, it has a high degree of maternal brooding and care of the young. It is now one of the world's most important warmwater cultured food fish. It is farmed in both extensive conditions and in super intensive (> 100 kg/m^3) recirculating and integrated hydroponic systems in tropical, subtropical, and even temperate countries.[4,5] The species has an amazing ability to adapt to its environment and has survived in an intensive water recirculating system with an atrophied caudal fin. Hereinafter, are six topics that provide an account of these adaptations and describe its survival even when deformed.

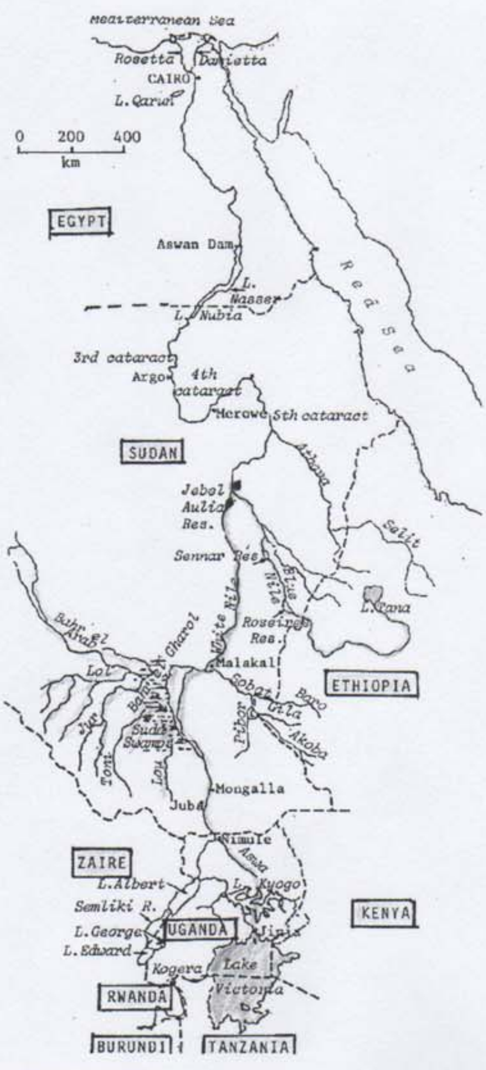

Figure 1
Rivers and Lakes of the Nile System.
(from Welcomme 1972)[6]

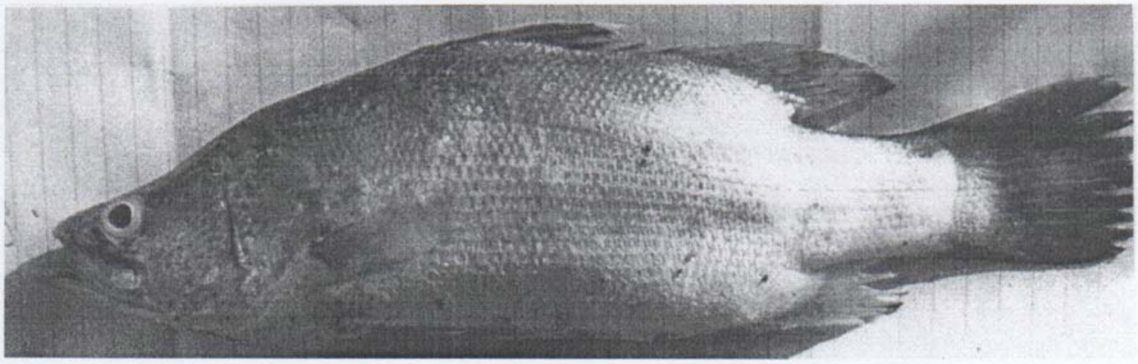

Figure 2
The exotic, carnivorous Nile perch, *Lates niloticus*. Joseph George photo

Ecological and Economic Domination in Lake Victoria

Natural selection is known to be the survival of the fittest, which means the most reproductively successful.[7] Of all the tilapiine species, *O. niloticus* in Lake Victoria—the largest lake in Africa with an area of 68,000 sq km (26,828 sq miles) and a depth of 95 m (Fig. 1)—could be one of the best examples to demonstrate natural selection. Although *O. niloticus* is not native to this lake, it has become an ecologically and economically dominant species, second only to another introduced species, the carnivorous Nile perch, *Lates niloticus* (Fig. 2), with which it co-exists and avoids direct competition for available resources. The Nile tilapia is the only tilapia species that could thrive in the presence of the predator Nile perch, a species that has had great impacts on the indigenous fishes of the lake. This is mainly because the Nile tilapia, unlike other tilapia species with primitive substratum habits, is a highly adapted mouth brooder (Fig. 3). The females carry the fertilized eggs in their mouths (Fig. 4) and can migrate long distances, allowing the species to disperse quickly, establishing and overpopulating favorable environments. Although it does not produce numerous progeny at each spawning, it provides its young with a high level of maternal care. Coupled with several extended reproductive periods each year, maternal care minimizes the risk of predation and enhances survival of the offspring.[8]

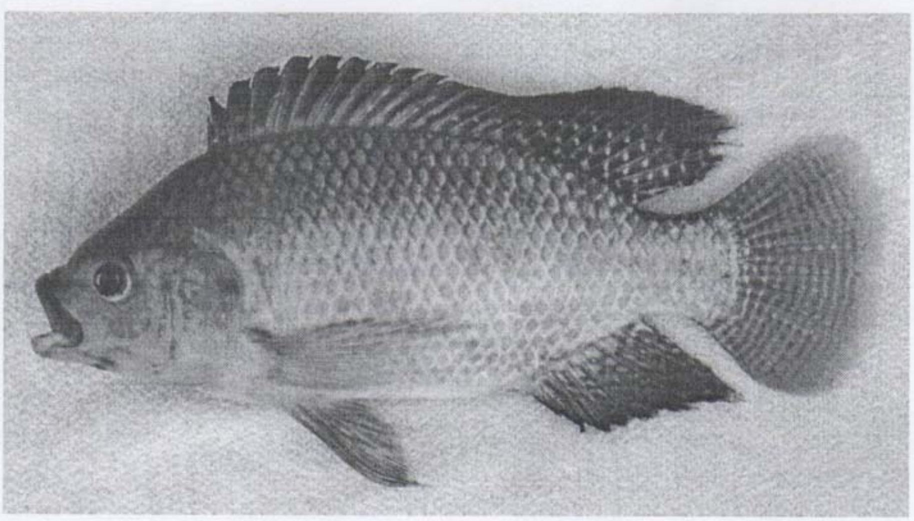

Figure 3
The Nile tilapia, *Oreochromis niloticus*—a colourful male before mating. Gary Chapman photo

Reproductive Behavior in Confined and Intensive Culture Conditions

Under confined conditions, *O. niloticus* has a great ability to switch from somatic to reproductive growth. In ponds or resevoirs, it matures at smaller sizes and younger ages and spawns more frequently than under natural conditions. Early maturation is coupled with a shorter life span and the production of a greater number of smaller eggs. This is homeostatic response to the environment and is not due a misunderstood 'stunting' problem that is thought to occur in cultured tilapia. Surprisingly, *O. niloticus* behaves quite differently in intensive recirculating systems than in pond conditions. Highly intensive stocking in a recirculating system eliminates reproduction and the fish resort to growing rapidly, which results in a desirable fish with a large body size within a short period of time. These adaptive abilities are responsible for the widespread distribution, plasticity, and success of *O. niloticus* as a colonizer.[4,8]

Structural Adaptations for Feeding and Reproduction

O. niloticus has the ability to solve problems related to feeding, incubation of eggs, etc. It has structural adaptations to being an omnivore, including its small pharyngeal teeth which are used to grind the coarse particles of its diet, a stomach with low pH (2.0) that helps to dissolve walls and membranes of cells, and a long intestine (up to 14 times the body length) that allows additional time for digestion and absorption. As a mouth brooder, it has a wider head than that of the primitive substrate spawner, which increases the capacity of the mouth for egg incubation. Furthermore, changes in the structure and behavior of very young fish also provide definitive morphological evidence of such an evolutionary sequence. The very young of substrate spawners are helpless at an early stage of development and have specialized larval organs called 'head glands' which enable them to anchor themselves to the substratum. These glands disappear as the larvae become sufficiently strong to swim effectively. Such glands are not required by larvae of mouth brooders because the larvae are provided with maternal care. However, it is very interesting to note that sections of the head of several mouth brooders have revealed non-functional rudiments of these organs, which clearly indicate that mouth brooders were derived from substrate spawners.[4,8]

Figure 4
A female *Oreochromis niloticus* taking its eggs into her mouth immediately after being fertilized by the male.
Gary Chapman photo

Reaction to Physical and Chemical Environmental Parameters

O. niloticus has adaptations that allow it to live in an extraordinary range of physical parameters, including temperature, dissolved oxygen, salinity, pH, ammonia, and other gases. It tolerates temperatures from 16° to 42°C, becomes inactive below 16°C, and does not survive below 9°C. Growth is poor at 20°C, optimum between 25° to 30° C, and greatest at 26°C. It reproduces at temperatures above 22°C . This adaptation to a stable temperature regime has limited its natural distribution to tropical areas. It can also tolerate a pH of 5 to 9.[3,4] Moreover, it inhabits areas where most other fish genera are unable to live, even under favorable food conditions, due to the fact that it tolerates dissolved oxygen levels as low as 0.1 ppm.[9] It also tolerates brackish water of 10 to 14 ppm and very high salinity (42 ppt) seawater. That is why it is assumed that tilapias evolved from a marine ancestor and that penetration to fresh water is secondary.[3,8,10]

Positive Reaction to Ammonia Toxicity Treatment in Intensive Recirculating Systems

With respect to ammonia, *O. niloticus,* as other fishes, excretes most of its nitrogenous waste through the gills in the form of ammonia. The toxicity of un-ionized ammonia depends on the amount of dissolved oxygen, with toxicity being higher when DO concentration is low. Therefore, controlling ammonia levels using bio-filters has revolutionized the aquaculture of *O. niloticus* in intensive recirculating systems due to its very positive reaction to higher oxygen levels. This fact, and other similar cases, refute the theory of the so-called 'living space factor effect' on fish growth, once believed to be responsible for fish not growing in limited or confined small areas.[11]

Ability to Survive in an Intensive Water Recirculating System even when Deformed

O. niloticus has survived in an intensive recirculating system even when with an atrophied caudal fin. Propulsion in this cichlid fish is achieved by the propagation of waves of muscular contractions along the body, of which the tail or caudal fin is a paddle-like extremity that contributes markedly to the propulsive effect. Such movements drive the fish forward. The conspicuous dorsal and anal fins are important in preventing rolling during swimming. They function like the keel of a boat as they can be raised or lowered according to the demands placed upon them. Both fins are supported by skeletal elements, simple spines and soft rays. Spines are restricted to the anterior portion of the dorsal and anal fins; they are stout and sharply pointed, while their flexible soft rays splay out towards their free end. The spines when erect present a set of spikes that can be used for defense. Besides the functions already described, fins have been utilized by *O. niloticus* for a variety of other purposes, some of which are mechanical.[8] The flexible rays of both the dorsal and anal fins, in the absence of an atrophied caudal fin, got extended beyond the posterior of the body and performed the action of a normal caudal fin (Fig. 5). This induced adaptation makes *O. niloticus* one of the most hardy and adaptive species in the aquatic environment.

Figure 5
A 13-cm *Oreochromis niloticus* with an atrophied caudal fin and the flexible rays of both the dorsal and anal fins extending beyond the posterior end of the body. Joseph George photo

Conclusion

There is a global consensus that *O. niloticus* is the most suitable species for aquaculture development. In fact, because all the above mentioned attributes are not shared with any other cultured species, it has become the most important aquaculture species of the 21st century.(5)

Recommendations

1) Fisheries and aquaculture scientists should record their observations of any fish abnormalities they encounter.
2) To overcome the so-called problem of 'stunting' in tilapia pond culture due to excessive reproduction, which is actually a homeostatic response to confined pond conditions, aquaculturists are advised to use high stocking densities and enough aeration and feed to control reproduction and encourage somatic growth, as is the case in confined intensive recirculating systems.

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Author

Thomas George (e-mail: profttg@yahoo.ca) is a Professor at the School of Fisheries Sciences, Faculty of Agricultural Technology and Fisheries Sciences, Al Neelain University, Khartoum, Sudan. He is also with Global Aquaculture Consultants in Toronto, Canada.