Experimental Approaches to the Saltwater Culture of Tilapias

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ICLARM research assistant Mei-Chan Huang at the National Sun Yat-Sen University, Kaohsiung, Taiwan, examining tilapia eggs to determine fertilization rate.

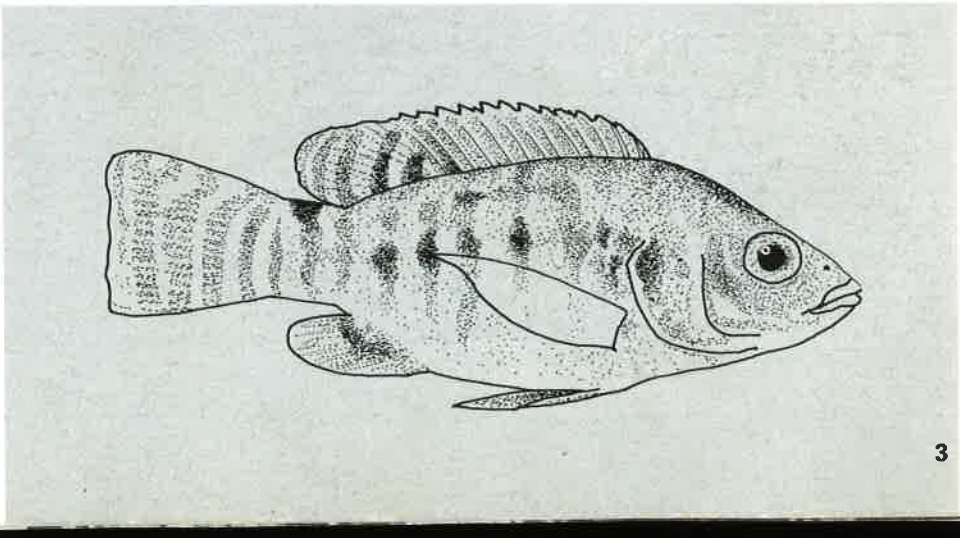
The tilapias are gaining economic prominence as cultured food fishes in countries such as Taiwan, the Philippines, Thailand and Indonesia. Although their culture is limited primarily to freshwater at present, the salt tolerance exhibited by some species has suggested the feasibility of expansion of culture activities into brackishwater and marine systems, thereby enabling the exploitation of underutilized arid and coastal regions for fish culture.

Results of earlier studies on the growth and survival of some commercially important tilapias at various salinities have suggested that although tilapias can be acclimatized and grown at elevated salinities, normal growth and reproduction are constrained by increasing salinity. Further progress in this area has been impeded by an inadequate research base on the biology and culture of tilapias with respect to salinity.

The generally used experimental approach to the problem of saltwater tilapia culture has been to produce seedstock from adults spawned in freshwater, followed by the transfer of these stocks to brackishwater or seawater for growout after an undefined period of early freshwater growth. Optimum age or size for transfer of freshwater reared stocks to seawater has not been standardized, nor has there been any information to suggest that time of transfer may influence growth or survival in seawater.

A two-year cooperative tilapia research project between ICLARM and the Council for Agricultural Planning and Development (CAPD) of the Government of Taiwan was initiated in July 1982. The primary objective was to develop techniques for the culture of tilapias in saline waters. An important segment of the research was conducted at the Institute of Marine Biology of the National Sun Yat-Sen University in Kaohsiung, Taiwan, where the salinity tolerance characteristics of some commercially important tilapia species in Taiwan were evaluated under controlled conditions. Some results of these studies and their implications for the culture of tilapias in saline waters are briefly summarized in this article.

In salmonid fish that are spawned in freshwater and migrate to the sea, the ability to survive in seawater develops during the early freshwater phase of the life cycle and pre-adapts them to subsequent seawater existence. These ontogenic changes in salinity tolerance are known to be closely related to size, which is therefore an important guide for determining the optimum time for release of hatchery-reared juveniles or for their transfer to seawater net pens. Failure to attain a critical size before



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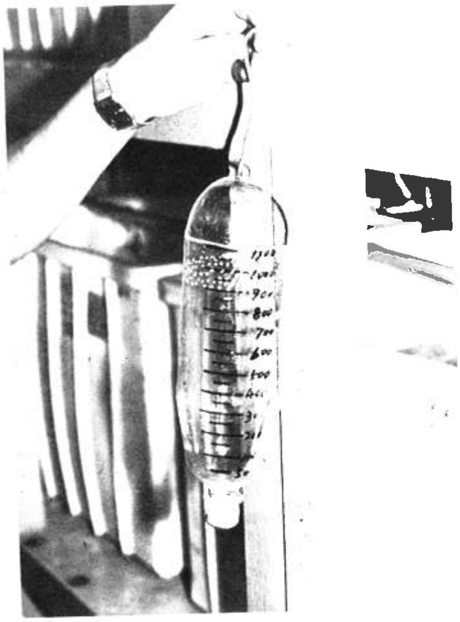
transfer results in mortality and stunting in seawater. In non-smolting salmonid species which normally spend their entire life in freshwater, salinity tolerance is also known to increase with body size. Fish size is also an important criterion for determining optimum time for seawater transfer in non-smolting species.

ICLARM-CAPD researchers in Taiwan have determined that similar changes in salinity tolerance occur in tilapias spawned and reared in freshwater. In the Nile tilapia *(Oreochromis niloticus)*, salinity tolerance, measured as mean survival time following direct freshwater to seawater transfer, remained low until 45 days post-hatching when tolerance began to improve with maximum tolerance by 150 days post-hatching. The blue tilapia *(O. aureus)* exhibited very similar age-specific changes in salinity tolerance. In contrast, hybrid progeny of female *O. mossambicus* and male *O. niloticus* (M X N hybrid) showed improved tolerance from day 7 and attained much higher survival levels. These ontogenic changes in salinity tolerance were determined to be more closely related to body size than to chronological age. However, salinity tolerance does not increase indefinitely with size. In *O. niloticus*, maximum salinity tolerance was acquired at a body length of about 52 mm and further size increases did not result in increased salinity tolerance.

Assuming that growth in seawater is compromised to maintain osmoregulation and that salinity tolerance is a fair indicator of osmoregulatory ability, maximum growth in seawater is likely to occur during periods of maximum tolerance. It follows that if freshwater-spawned and reared stocks are to be grown in seawater, best results are likely to be achieved by implementing transfer to brackishwater or seawater at size of maximum salinity tolerance. Production experiments comparing the growth of tilapias transferred at different sizes to saline water are required to test this hypothesis.



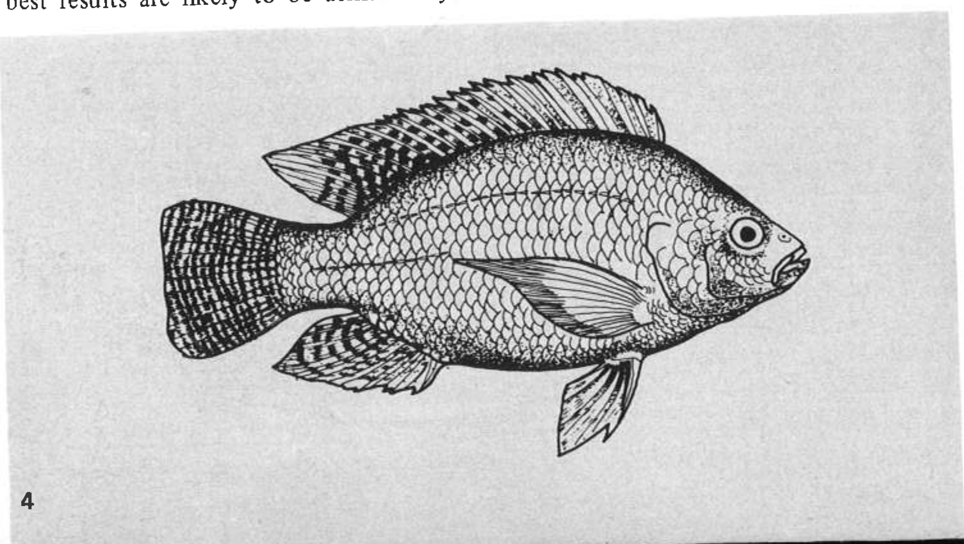
Experimental egg incubator used in the ICLARM-CAPD research.

A knowledge of size-related differences in salinity tolerance in the tilapias has some important practical implications for the saltwater tilapia culturist in arid areas. In addition to providing a rational basis for selecting the optimal time for transfer of freshwater-spawned and reared stocks to seawater for growout, it permits judicious use of limited freshwater supplies by allowing transfer to be implemented at the earliest possible time. When freshwater is limited, the amount of fish that can be produced in freshwater will limit total production. Therefore, under these circumstances, it would be economically advantageous to implement seawater transfer as early as possible by maximizing initial freshwater growth to size of maximum salinity tolerance. This may be achieved, for example, through temperature control in combination with recirculation and aeration systems to minimize volume. Maximal freshwater growth may also be achieved through the application of growth promoters such as anabolic steroids and thyroid hormones.

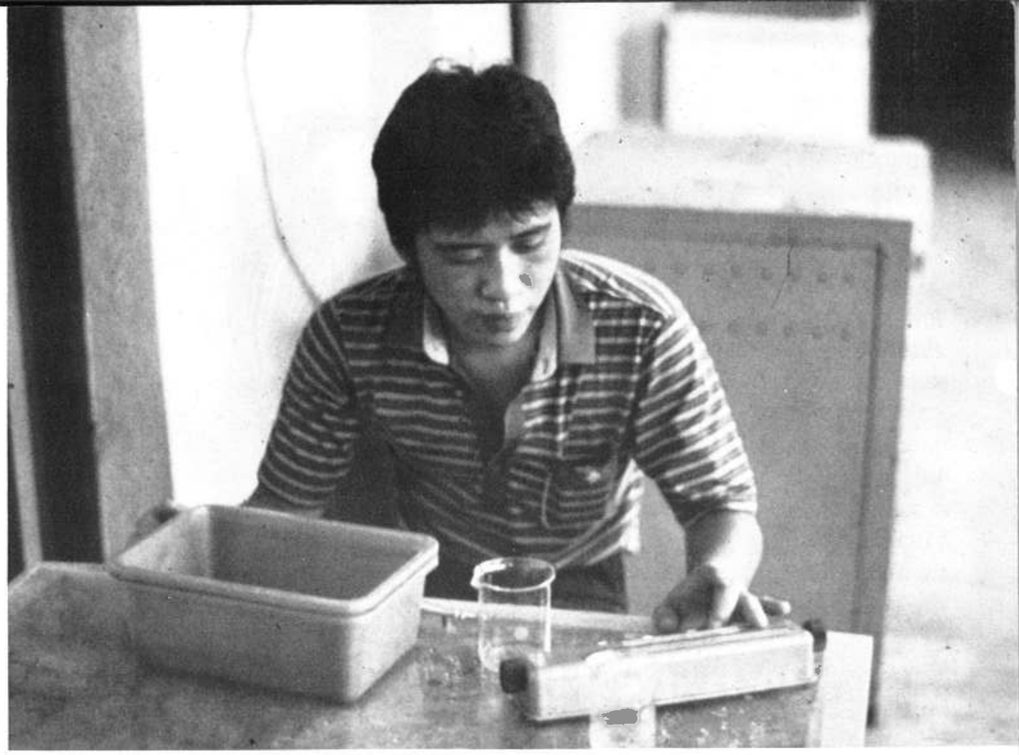
Hybridization experiments in salmonids have demonstrated the feasibility of producing progeny which can be transferred to seawater at very small sizes, which also reduces freshwater requirements. Early seawater transfer of tilapias at small sizes may similarly be achieved through utilization of hybrids such as those of *O. mossambicus* and *O. niloticus* which exhibit relatively rapid increases in salinity tolerance with size. Hybrids of *O. niloticus* and *O. mossambicus* are known to grow faster with better food conversion efficiency than either parent species. Red tilapia, thought to be a hybrid between *O. niloticus* and *O. mossambicus*, were recently reported by the Tungkang Marine Laboratory in Taiwan to grow faster in brackishwater and seawater than in freshwater during mixed-sex rearing experiments. All of these results support the possibility of producing hybrids between *O. mossambicus* and *O. niloticus* which exhibit good growth and feed conversion under saline conditions.

When freshwater is severely limited, costs associated with spawning and early rearing in freshwater may still outweigh the benefits of improved survival and growth attributable to the selection of optimal seawater transfer times. An alternative approach to the problem of saltwater tilapia culture evaluated by ICLARM-CAPD researchers in Taiwan was to pre-expose fish to low concentrations of seawater at very early stages of their life cycle in order to pre-adapt them to rearing at higher salinities.

Fertilized eggs of *O. niloticus* spawned in freshwater were removed from the mouth of the parent female one day after spawning and artificially incubated at elevated salinities. Mortality during artificial incubation occurred primarily during early embryonic development



and generally stabilized after hatching. Survival patterns during incubation at low salinities (5 and 10 ppt) were very similar to those observed in freshwater. In higher salinities (15, 20, 25 and 32 ppt), mean survival values by the sixth day after hatching declined to 56.3, 37.9, 20.0 and 0%, respectively. Interestingly, freshwater-spawned eggs were successfully incubated and hatched at salinities as high as 25 ppt, whereas 7 to 395-day old fry and fingerlings were unable to survive direct transfer to this salinity. These results possibly reflect a greater degree of adaptability of early embryos to high environmental salinity than fry or fingerlings. For saline water-hatched fry, increased hatching salinity improved salinity tolerance.



Researcher checking and counting newly-hatched tilapia larvae.

Reproductive Performance

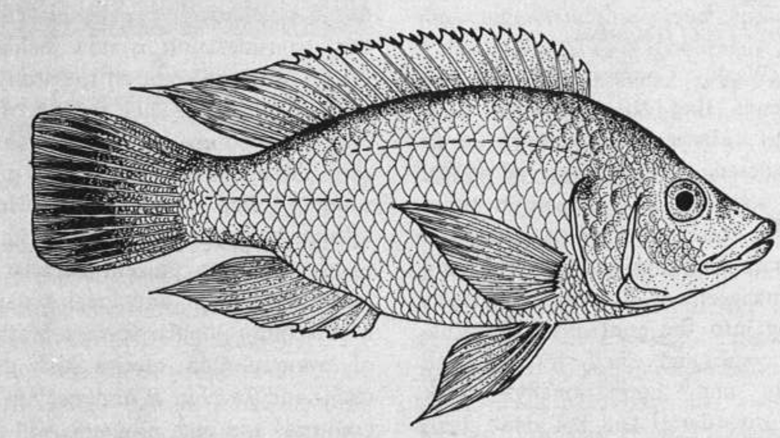
Experimental evidence on reproductive performance of tilapias at various salinities has been lacking. ICLARM-CAPD researchers monitored the reproductive performance of a yearling *O. niloticus* broodstock under laboratory conditions at various salinities. Spawning was observed in salinities ranging from freshwater to full seawater (32 ppt). However, the inhibitory effect of high salinity on reproduction was evidenced by considerably lowered hatching successes at 10 ppt (32.7%) and 15 ppt (36.7%). Extremely poor hatching success resulted with eggs spawned in full seawater with only a few abnormal larvae produced. No fry were produced in full seawater despite the fact that eggs continued to be produced and spawned at this salinity.

Rearing at high salinities has been suggested as a way to prevent overpopulation in fishponds without the need for sex separation. Although *O. niloticus* fail to reproduce in full seawater, energy is nevertheless channeled into egg production in females of small sizes. Therefore, all-male rearing through sex separation, sex reversal or hybridization are still appropriate techniques for maximizing growth rates during rearing at high salinities.

The ICLARM-CAPD study also found that for saline water-spawned fry, increased spawning salinity also improved salinity tolerance. However, at equivalent salinity, early exposure (spawning) produced progeny of comparatively higher salinity tolerance than those spawned in freshwater and hatched at elevated salinity.

As results have demonstrated that salinity tolerance varies considerably with age, size, and salinity exposure history of the individual, it is important that these factors be defined and standardized when designing experiments for evaluating the growth performance of tilapias in relation to environmental salinity.

The genetic approach to developing strains or hybrids which exhibit good growth and survival in seawater remains an important research priority for saltwater tilapia culture. In addition, simple non-genetic techniques such as early salinity exposure and selection of optimal transfer times may help to maximize the potential of moderately salt-tolerant species, such as *O. niloticus*, for survival and growth during culture at supra-optimal salinities. ●



Two reports giving details of the ICLARM-CAPD research have been published. Details on p. 22.