

A Review of Seawater Acclimation Procedures for Commercially Important Euryhaline Tilapias

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Abstract

Procedures for acclimating commercially important euryhaline tilapias to seawater are reviewed. Single-step acclimation (intermediate salinity directly to the final salinity) has been most often used for *Oreochromis mossambicus* (Peters) and requires only one day at an intermediate salinity with no resulting mortality. Other tilapias which are less salt tolerant have required multistep acclimation (gradual increase in salinity). Time required for seawater acclimation with no mortality ranges from four days for *O. aureus* (Steindachner) to eight days for *O. niloticus*. Research needs are discussed.

Mariculture, whether onshore or in the open ocean, is receiving significant and increasing attention. In part, the future expansion of aquaculture lies in intensification of freshwater culture (Lorio and Perschbacher, in press) and in utilizing seawater. Farming the oceans also realizes the greater productivity and value derived from culture practice, as opposed to the common property capture fisheries.

Many island and arid nations are currently experiencing freshwater shortages, but have abundant available seawater for aquaculture. However, most candidates for saltwater aquaculture have complicated and delicate life cycles. Acclimating a euryhaline, cultured species to seawater offers advantages of known and economic culture practices. Tilapias, especially of the genus *Oreochromis*, are one such group that has been explored because of high salinity tolerances, ease in spawning and rearing, fast growth, hardiness in confined and eutrophic environments, low feed cost and market acceptability. The usefulness of these fishes for seawater culture in Saudi Arabia and extensive acclimation trials of the

commercially important euryhaline species have been reported by Al-Amoudi (1987a, 1987b). At the 1988 meeting of the World Aquaculture Society, seawater production research was reported with red hybrid tilapia in cages in the Bahamas (Clark et al. 1989) and in tidal ponds in the Philippines (Thomforde and Chiu 1989); with *O. niloticus* (female) x *O. aureus* (male) in a recirculation system in Taiwan (Shiau and Huang 1989); and with *O. spilurus* (Günther) in raceways in Kuwait (Cruz et al. 1990).

Stickney (1986) has most recently reviewed the salinity tolerances of commercially important euryhaline tilapias. Seawater culture of commercial species appears to be of the order from least successful to most: *Tilapia zillii* Gervais, *O. mossambicus*, *O. niloticus*, *O. aureus*, *O. spilurus* and *O. mossambicus* hybrids. The first two exhibit slow growth and stunting; and the next two suffer temperature sensitivity and disease in seawater (Stickney 1986). The acclimation process has been studied in some detail for *O. mossambicus* and is presumably similar in the other tilapias. The major adaptation response occurs by a proliferation of salt-secreting cells on the gills (Fishelson 1980; Foskett et al. 1981; Pange 1985; Hwang 1987), although adaptive changes in the kidney have also been noted (Fukusho 1969). The complete response requires 24 hours in *O. mossambicus* (Fishelson 1980) and apparently longer in the other species, in which also the chloride cells do not develop as large as those in *O. mossambicus* (Cioni et al. 1991). Thus, the procedure for *O. mossambicus* has commonly involved single-step acclimation or acclimation from one to several days in a partial seawater medium followed by direct transfer to seawater (Table 1). Other species require a multistep acclimation procedure of gradually increasing the salinity until full strength seawater is reached (Table 2). Based on current research, this may take as little as two days for *O. mossambicus* x *O. niloticus* hybrids (Liao and Chang 1983); four days for *O. aureus* (Chervinski and Zorn 1974; Al-Amoudi 1987a), *O. spilurus* (Al-Amoudi 1987a) and *T. zillii* (Chervinski and Hering 1973); seven days for *O. aureus* x *O. niloticus* (Al-Amoudi 1987a) and eight days for *O. niloticus* (Al-Amoudi 1987a). Acclimation to hypersalinities of 60-70 ppt has been accomplished with *O. mossambicus* by multistep procedures (Table 3). The above procedures that did not present mortality data must be regarded as provisional.

Although greatest seawater culture and production interest is in the red hybrid tilapias, Stickney (1986) also noted that red

Table 1. Procedures used for single-step seawater acclimation of freshwater spawned and incubated euryhaline tilapias.

| Species | Weight (g) | Acclimation procedure (ppt-hours) | Final salinity (ppt) | Average mortality (%) | Source |
|-----------------------|------------|-----------------------------------|----------------------|-----------------------|-----------------------|
| <i>O. mossambicus</i> | 3 | 14-24 | 36 | * | Potts et al. (1967) |
| <i>O. mossambicus</i> | 30-40 | 12-48 | 36 | 0.0 | Foskett et al. (1981) |
| <i>O. mossambicus</i> | 16 | 10-192 | 33 | 0.0 | Jurss et al. (1984) |
| <i>O. mossambicus</i> | 5-10 | 20-24 | 30 | 0.0 | Hwang (1987) |

*Not reported

coloration alone may not translate into increased demand and price among price-conscious consumers. Brass et al. (1990) found that Florida red hybrid tilapia seawater cage culture was not economically feasible in Haiti. Additional problems are the variable color patterns encountered in breeding (Behrends et al. 1982), the variable growth of these phenotypes (Meriwether et al. 1984) and low survival rates (El Gamal et al. 1988). An especially undesirable combination is the albino, white with black eyes, which is ultimately a lethal phenotype (Galman et al. 1988).

Additional research is needed to determine survival rate for procedures where survival has not been reported (many acclimation procedures were not experimental objectives of the respective studies). Acclimation times may also be reduced and labor and equipment simplified. Balarin and Haller (1982) reported that *O. spilurus* has survived direct transfer to 33 ppt, and no mortality was observed during single-step acclimation of 0.3-g Florida red hybrid tilapia to seawater with an acclimation salinity of 19 ppt and 22 hours acclimation (P. Perschbacher, unpubl. data). Addition of 10% sodium chloride to diets of several species of tilapias has increased salinity tolerances (Al-Amoudi 1987b). Spawning and hatching in saline water has increased the salinity tolerance of *O. niloticus* (Watanabe et al. 1985a). A high calcium level in the acclimation medium has also increased salinity tolerance in *Mugil cephalus*

Table 2. Procedures used for multistep seawater acclimation of freshwater spawned and incubated euryhaline tilapias.

| Species | Weight (g) | Acclimation procedure (ppt-hours) | Final salinity (ppt) | Average mortality (%) | Source |
|--|----------------------------|-----------------------------------|----------------------|-----------------------|-----------------------------|
| <i>O.m.</i> | 4 | 18-48, 27-48 | 36 | 0.0 | Al-Amoudi (1987a) |
| <i>O.m.</i> x <i>O.h.</i> (red variant) | fry | +8/24 from freshwater | 32-34 | * | Murray and Mitsui (1982) |
| <i>O.m.</i> x <i>O.</i> <i>macrochir</i> (red variant) | 411Q, 501O ⁿ | gradual, 120 from freshwater | 32 | * | LeaMaster et al. (1990) |
| <i>O.m.</i> x <i>O.n.</i> (red variant) | 16 | gradual, 48 from freshwater | 34 | * | Liao and Chang (1983) |
| <i>O.m.</i> x <i>O.n.</i> | fry | +5/24 from freshwater | 32 | * | Villegas (1990) |
| <i>O.h.</i> x <i>O.m.</i> (red variant) | 2.4 | +5/24 from freshwater | 37 | 1.2 | Watanabe et al. (1990) |
| <i>O. spilurus</i> | 4 | 18-48, 27-48 | 36 | 3.3 | Al-Amoudi (1987a) |
| <i>O. spilurus</i> | fry | gradual, 168 from 3-5 ppt | 36 | * | Cruz et al. (1990) |
| <i>S. melanotheron</i> | 411Q, 501O ⁿ | gradual, 120 from freshwater | 32 | * | LeaMaster et al. (1990) |
| <i>O.a.</i> | 4 | 18-48, 27-48 | 36 | 0.0 | Al-Amoudi (1987a) |
| <i>O.a.</i> x <i>O.n.</i> | 4 | 18-72, 27-96 | 36 | 0.0 | Al-Amoudi (1987a) |
| <i>O.n.</i> | 4 | 18-96, 27-96 | 36 | 0.0 | Al-Amoudi (1987a) |
| <i>O.n.</i> x <i>O.a.</i> | 1.6 | +5/24 from freshwater | 32-35 | * | Shiau and Huang (1990) |

*Not reported

a=*auureus*; m=*mossambicus*; n=*niloticus*; h=*hornorum*

Linnaeus (Auld 1972) and *Fundulus kansae* (Garman) (Potts and Fleming 1970). Fish age and size also affect acclimation. Larger, older individuals are more salt tolerant than smaller ones of the same species (Watanabe et al. 1985b; Perschbacher and McGeachin 1988). Watanabe et al. (1990) have shown that age may be more important than size at which acclimated for a given species.

Table 3. Procedures used for acclimation to hypersalinities of freshwater spawned and incubated euryhaline tilapias.

| Species | Weight (g) | Acclimation procedure (ppt-hours) | Final salinity (ppt) | Average mortality (%) | Source |
|-----------------------|------------|-----------------------------------|----------------------|-----------------------|------------------------------|
| <i>O. mossambicus</i> | 3 | 72-96 (salinities not specified) | 72 | * | Potts et al. (1967) |
| <i>O. mossambicus</i> | 6-10 | +5/72 from freshwater | 60 | * | Assem and Hanke (1979) |
| <i>T. zillii</i> | 1-3 | +10%/24 from 22 ppt | 39 | 13.5 | Chervinski and Hering (1973) |
| <i>O. aureus</i> | * | +10%/24 from 22 ppt | 39 | * | Chervinski and Zorn (1974) |

*Not reported

Water-to-water transfer to seawater produced less mortality in salmonids than dip-netting (Flagg and Harrell 1990) and this may be true with tilapias also.

Conversely, poor nutrition may increase mortality during acclimation. Starvation has been shown to reduce Na/K-ATPase, important in osmoregulation, by approximately 40% at 33 ppt (Jurss et al. 1984).

Several other species should also be studied. *Sarotherodon melanotheron heudeloti* Dumeril is maintaining a viable population in Tampa Bay, Florida, and its substantial fishery and limited environmental effects have been noted by Springer and Finucane (1963), and Finucane and Rinckey (1964). Trewavas (1983) indicated that the salinity tolerance of this species is greater than that of *O. niloticus* but less than that of *T. zillii* and in need of research. Trewavas' (1983) treatise on the *Oreochromis* group includes several little-examined species that reach marketable size and are euryhaline: *O. mortimeri* Trewavas attains 2.7 kg and is similar to *O. mossambicus* in salinity tolerance; *O. andersonii* (De Castelnau) attains 1.8-2.3 kg and has been reported to tolerate salinities to 26 ppt; and *O. angolensis* Trewavas attains 20 cm and is red with white spots.

At present, hybrids of *O. mossambicus* and *O. spilurus* appear most promising for seawater culture. Production of these species is expected within the next few years. Studies on environmental impacts should begin prior to this phase.

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