Rearing Experiments with Florida Red Tilapia for Saltwater Culture

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ABSTRACT

Rearing experiments with Florida red tilapia hybrid (*Oreochromis urolepis hornorum* female X *O. mossambicus* male) for saltwater culture are being conducted under laboratory and field conditions at the Caribbean Marine Research Center in the central Bahamas. A pilot-scale hatchery, supporting experimental research as well as extension projects in the Caribbean, has been in operation since April 1987 on Lee Stocking Island (Exuma Cays, Bahamas).

Experimental studies have determined the effects of salinity on growth and reproduction in Florida red tilapia and have compared seawater survival and growth of progeny spawned at different salinities. Results provide a basis for developing seawater acclimation methods that minimize freshwater requirements for broodstock holding and early fry rearing and that maximize survival and growth in seawater.

Other studies have assessed the utility of organic fertilizers (i.e., chicken manure) in lieu of prepared feeds for fingerling production in seawater tanks. Growth and survival from fingerling through market stages in floating cages utilizing prepared feeds is under study at a marine site on Great Exuma, Bahamas. A feasibility study on saltwater cage culture of Florida red tilapia in Haiti is also in progress.

Results to date indicate a remarkably high adaptability of the Florida red hybrid strain to seawater and suggest an excellent potential for their utilization in brackishwater and marine aquaculture in coastal areas of the Caribbean.

INTRODUCTION

The Caribbean Marine Research Center (CMRC) is a private, non-profit research organization located on Lee Stocking Island, Exuma Cays, Bahamas. Since July 1984, CMRC has undertaken a program of research aimed at developing technology for marine aquaculture of tilapia (a euryhaline, freshwater finfish group) as an inexpensive source of animal protein for Caribbean Island and similar regions where freshwater resources are limiting (Watanabe *et al.*, 1989). Although not indigenous marine species, tilapias were identified as the finfish group best meeting important criteria established by CMRC including: acceptance as food fish, ease of breeding and rearing, ability to utilize a variety of inexpensive feeds of both plant and animal origin, and adaptability of culture methods to lesser developed regions. In addition,

euryhaline tilapias are generally able to tolerate a wide range of salinities, suggesting a potential for culture in brackishwater or marine systems. Suitability for high-density culture in cages was also considered an important attribute that would permit farming in coastal waters, thereby minimizing costs associated with construction and maintenance of land-based production systems.

Initial attempts by CMRC to rear blue tilapia (*O. aureus*) in floating sea cages in the Bahamas were met with limited success (McGeachin *et al.*, 1987). Subsequent studies revealed that Florida red tilapia, a hybrid strain originally derived by crossing *O. urolepis hornorum* (female) with *O. mossambicus* (male) (Sipe, 1979), were highly tolerant of seawater, and studies on culture methodology were initiated. Experimental work at CMRC has sought to obtain basic information on the biology of the Florida red tilapia hybrid with respect to salinity tolerance as well as to assess production performance in seawater. Work has also begun to extend saltwater cage culture of Florida red tilapia to other areas of the Caribbean Basin, beginning in Haiti. In this paper, recent progress in experimental saltwater culture of Florida red tilapia is summarized.

EFFECTS OF SALINITY ON GROWTH OF FLORIDA RED TILAPIA

Growth of Juvenile, Monosex Males at Different Salinities

Little information is available on the influence of salinity on growth in tilapias. The effects of salinity on growth of Florida red tilapia, previously unknown, were studied in juvenile, monosex males under controlled photoperiod (12 L: 12 D) and temperature (28°C). A high euryhaline capacity of the Florida red tilapia strain was evidenced by faster growth rates in brackish and seawater than in freshwater, although results appeared to be modified by stocking density. At a high density (20 fish/ 200-1 tank), growth in freshwater was comparable to growth at 10 ppt and above. Growth under 36 ppt at a low density (10 fish/ tank) was lower than that at a high density. At an intermediate density (15 fish/ tank), however, there was a clear trend toward increased growth with salinity due to increased food consumption and declining conversion ratios with salinity (Watanabe *et al.*, 1988a,b). These results support previous reports of faster growth in brackish and seawater than in freshwater in certain tilapias including *O. mossambicus* (Canagaratnam, 1966; Jurss *et al.*, 1984) and Taiwanese red tilapia hybrids (*O. mossambicus* x *O. niloticus*) (Liao and Chang, 1983).

Influence Of Behavior On Growth At Different Salinities

The apparent density-dependent differences in growth response to salinity observed in these studies suggested that behavioral factors influenced these results. Further investigations revealed that agonistic encounters among fish as well as percentages of fish with damaged fins (due to agonistic encounters) declined with salinity, suggesting that growth response to salinity was

influenced by inhibitory effects of territorial aggression which was mitigated by increasing salinity (Watanabe *et al.*, 1988a,b). This suggested that aggression impairs growth by lowering food consumption (appetite) and increasing conversion ratios. Hence, as aggression was mitigated by increasing salinity, growth was improved. That behavioral interactions may exert inhibitory effects on growth which vary with salinity was previously suggested for Taiwanese red tilapia (Liao and Chang, 1983).

Growth in Seawater Pools Under Maximum Feeding

Survival and growth of monosex male Florida red tilapia (1.3 g mean weight) in seawater pools (23 m^3) under conditions of maximum feeding with a prepared diet (30% protein) were studied. A mean body weight of 467 g was attained after 170 days at a survival rate of 89% (Ernst *et al.*, MS). Mean specific growth rates decreased as a function of fish size from 9.2%/day to 0.8%/day during the 170 day period, and exceeded reported values for Taiwanese red tilapia hybrids in freshwater. Food conversion ratios (dry weight: wet weight) ranged from 1.5 to 1.8. A high growth capacity and excellent food conversion ratios in seawater from fingerling through market stages were demonstrated.

PILOT HATCHERY FOR SALTWATER TILAPIA CULTURE

The methods that have been developed at CMRC for culture of Florida red tilapia in seawater are relatively simple: Spawning occurs naturally in brood tanks maintained at low salinity (3-6 ppt groundwater). Periodically, free-swimming fry are collected from the pools while unhatched eggs and yolksac fry are manually removed from mouthbrooding females and incubated artificially. Yolksac-absorbed fry are sex-reversed by feeding a diet containing an androgenic hormone (17 - ethynyltestosterone) for 28 days to transform genotypic females to phenotypic males (Guerrero, 1975). After sex-reversal, fry are gradually acclimated to seawater over a period of 1 week, then transferred to nursery tanks for a period of rapid growth prior to stocking in sea cages.

Construction of a new pilot-scale hatchery to support experimental research as well as extension projects in the Caribbean was completed in April 1987 on Lee Stocking Island. The design and operation of the hatchery, consisting of six 34-m^3 broodfish tanks, six 6.5-1 egg incubators, sixteen 560-1 rearing tanks for sex reversal of fry, and eight 4.9-m^3 tanks for seawater acclimation of sex-reversed fry, were described in detail by Ernst (1989). The hatchery incorporated a system for recirculation of water through biofilters, a critical design feature in the Bahamas where limited groundwater resources must be conserved. Multiple recirculation systems permit simultaneous testing of separate salinity regimes for broodstock holding and sex-reversal so that optimal salinities for maintaining broodstock and rates for acclimation of fry to seawater

may be determined experimentally. Spawning, incubation of eggs and sex-reversal of fry may be conducted at any salinity up to that of full seawater (36-37 ppt). During the period April 9 to July 27, 1987, a total of 796,613 and 536,668 eggs and fry were collected from hatchery broodfish units maintained under salinities of 3-6 ppt and 18 ppt, respectively (Ernst, unpublished data).

DEVELOPMENT OF METHODS FOR ADAPTATION OF FLORIDA RED TILAPIA TO SEAWATER

Gradual acclimation of fry to seawater following sex-reversal (approximately 35 days post-hatching) has been found to generally result in good survival and growth in seawater. However, the requirement for low-salinity water for maintaining broodstock and for early rearing increases infrastructure costs for recirculation of water and restricts the siting of future hatcheries to areas where low-salinity water is available. Considerable research emphasis at CMRC has been placed on the development of seawater acclimation methods that minimize the requirement for low-salinity water during the hatchery phase of production and that maximize survival and growth in seawater.

Selection of Optimal Life Stage for Seawater Transfer

Low-salinity water requirements during the hatchery phase of production may be reduced by acclimating stocks to seawater at early stages of development. Early acclimation may be accomplished by initiating seawater transfer during the early fry stages or by incubating and hatching eggs at elevated salinities (Watanabe *et al.*, 1985a,b). This approach may be limited by the fact that, in tilapias, salinity tolerance varies ontogenetically, suggesting that seawater survival and growth may be affected by the life stage at which seawater acclimation is begun (Watanabe *et al.*, 1985b). Preliminary results of studies on responses of Florida red tilapia transferred to seawater at different times of the sex-reversal period suggest that survival was relatively poor among groups acclimated to seawater before 35 days post-hatching (Watanabe, unpublished data). Corresponding effects on growth are under study. Additional studies are required to determine the relationships among salinity tolerance, age, and body size to provide a practical basis for determining optimal time for transfer to seawater.

Production of Seedstock in Brackish- or Seawater

One approach to reducing low-salinity water requirements for holding broodstock and early rearing is to maintain and spawn broodstock at elevated salinities. There is evidence suggesting that in tilapias, exposure to a saline environment at the early embryonic stages may confer adaptive advantages to these individuals which improve growth and survival in seawater (Watanabe *et*

al., 1985a). This approach is generally limited by the fact that, in tilapias, normal reproduction is inhibited by increasing salinity (Ridha *et al.*, 1985; Watanabe and Kuo, 1985).

The effects of salinity on reproductive performance of Florida red tilapia were studied. Adult breeders were maintained in laboratory aquaria at salinities of 1, 9, 18, 27 and 36 ppt under controlled photoperiod (16 L: 8 D) and temperature (28 °C). Egg production and spawning were observed at all salinities, although an inhibitory effect of salinity on reproductive performance was evidenced by a marked decline in fertilization and hatching success at salinities above 18 ppt (Burnett, unpublished data). Nevertheless, viable yolksac-absorbed fry were produced at all salinities, including full seawater (36 ppt). These results suggest that although seed production at salinities as high as 36 ppt is possible, productivity declines at salinities higher than 18 ppt. Seed production at high salinity may be practical in areas where low-salinity water is lacking.

Seawater Survival and Growth of Progeny Spawned at Different Salinities

A study comparing survival and growth of progeny spawned in brackishwater (18 ppt) with those spawned in freshwater (2 ppt) showed that survival and growth at a mean water temperature of 27°C were not significantly different between these groups. However, when temperatures abruptly declined to below 25°C, survival and growth remained significantly higher in brackishwater-spawned progeny (Watanabe *et al.*, MS). These results suggest that seawater survival and growth are not impaired in progeny spawned at salinities as high as 18 ppt, and that brackishwater-spawned progeny possess a higher capacity for survival and growth in seawater than freshwater-spawned progeny when environmental temperatures approach lower tolerance limits.

Seawater survival and growth of progeny spawned at salinities higher than 18 ppt have not been studied. Available information suggests that advantages of spawning at high salinities will be gained at the cost of lowered seed production at these salinities.

DEVELOPMENT OF COST-EFFECTIVE FEEDS FOR SEAWATER CULTURE

An approach to reducing costs associated with use of prepared diets during nursery culture in land-based systems, is the indirect utilization of cheap animal wastes as fertilizer for production of natural planktonic foods. To assess the feasibility of this approach, growth of Florida red tilapia receiving a prepared diet was compared to fish reared in seawater pools enriched with chicken manure. Growth of fish in the fed pools continued at an exponential rate to day 80, while growth in manured pools became asymptotic by about day 30, indicating that food availability in manured pools was growth limiting (Ernst *et*

al., MS). Significant differences in fish growth among manured pools were evident, suggesting that food availability varied significantly between manured pools. Plankton and fish gut-content analyses supported the conclusion that identical methods of manuring do not necessarily produce identical biological communities and fish growth (Grover *et al.*, 1987; O'Brien, unpublished data). Further research is needed to determine fish densities at which a sustainable yield of the food resource and acceptable fish growth rates could be maintained. Supplementary feeding with prepared diets in manured systems may also be practical.

REARING EXPERIMENTS IN FLOATING SEA CAGES

In May 1986, a pilot study was conducted to assess survival and growth of Florida red tilapia in floating cages placed in a seawater (37-40 ppt) channel near Barraterre on Great Exuma, Bahamas (Watanabe *et al.*, 1989). The technical feasibility of rearing Florida red tilapia at high densities in floating sea cages using prepared diets was demonstrated in this study.

A detailed cage production study involving 9,600 sex-reversed fingerlings (10.1 g mean weight) and twenty-eight 1 m^3 experimental cage units was initiated at Barraterre in August 1987. The effects of feed rate and stocking density on growth from fingerling through market stages, using a commercially available diet (Purina Tilapia Chow, 32% protein), are being assessed. After 43 days of culture, mortalities were negligible, and mean body weights among the experimental groups ranged from 48.6 to 78.2 g, while food conversion rations (dry weight: wet weight) ranged from 1.4 to 2.6 (Clark, unpublished data).

APPLICATION STUDIES IN THE CARIBBEAN

In Haiti, natural fish stocks have been depleted by heavy exploitation. A previous aquaculture demonstration project in la Gonave, Haiti has shown that blue tilapia (*O. aureus*) are acceptable as food fish and bring competitive prices at the marketplace (Stickney and Kohler, 1986). Lack of freshwater and machinery for pond construction were primary constraints toward production of significant numbers of fish.

The Caribbean Marine Research Center has recently initiated a feasibility study on saltwater cage culture of Florida red tilapia in Haiti. Twenty-five marine or brackishwater sites in four bays along the northern coast of Haiti, including Baie de l'Acul, Baie de Cap Haitien, Baie de Caracol and Baie de Ft. Liberté, were identified as potentially suitable for cage culture of Florida red tilapia (Rust *et al.*, 1991). A study on production of Florida red tilapia in sea cages is currently in progress at Baie de Ft. Liberté. In addition to determining the technical feasibility of seawater cage culture in Haiti, social, cultural and economic factors affecting the extension of this technology to coastal communities are being assessed (Brass *et al.*, *1991*).

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