TILAPIA CULTURE IN BRAZIL

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ABSTRACT

Nile tilapia was introduced to Brazil in 1971 from the Ivory Coast and a red tilapia hybrid arrived in 1981 from Florida, USA. Production of Nile tilapia captured by commercial fishers from public reservoirs in northeastern Brazil reached 5,000 t by 1979. Pond culture of tilapia was slow to develop until 1990 when male tilapia fingerlings produced by hormone sex reversal of fry and pelleted fish feeds became widely available. Tilapia are farmed in a variety of systems, including semi-intensive culture in ponds fertilized with animal manures to intensive culture in flowing water raceways and in floating cages. The majority of farmed tilapia is sold live to fee-fishing operations but food fish markets are growing rapidly. Most farmed tilapia is sold domestically; only 1,300 kg of frozen tilapia filets were exported in 1997. Most tilapia are farmed in the states of Santa Catarina, Paraná and São Paulo located in southern and southeastern Brazil. While statistics are unavailable, half of the yearly farmed fish production in Brazil is probably tilapia, approximately 20,000–25,000 t.

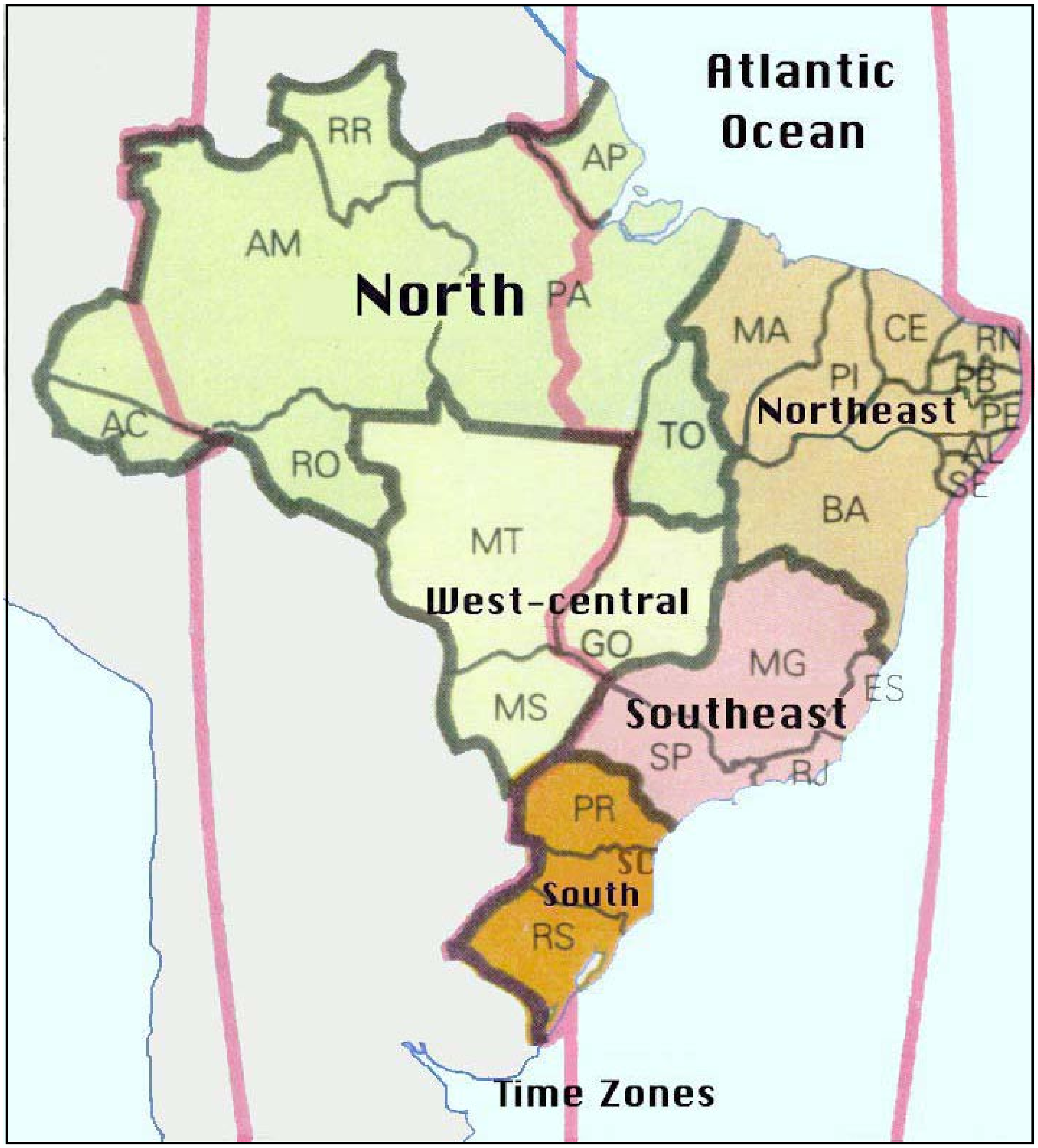
INTRODUCTION

Brazil is a country of great contrasts, ranging from the wealthy, industrialized, densely populated state of São Paulo to the underdeveloped, sparsely populated Amazon River Basin. Brazil has the 5th largest land mass in the world, larger than the continental United States. The population of Brazil, the fifth largest in the world, is 160 million; 57% of the inhabitants live in the southern and southeastern regions (Figure 1). Brazil has the ninth largest Gross National Product (GNP) in the world. Seven states in the southern and southeastern regions compose 18% of the Brazilian territory and 78% of the GNP. In comparison, the northern region of Brazil located within the Amazon River basin is composed of 7 states with 45% of the Brazilian land area, 7% of the Brazilian population and 3% of the GNP (Martins 1996; Instituto Brasileiro de Geografia e Estatística 1997).

Brazil is a world leader in the production and export of processed chicken and pork but fish culture has never played an important role in the production of animal protein in Brazil. Brazilians consume 5.4 kg of seafood/capita/y (Coelho 1997). However, inhabitants in northern Brazil consume 55 kg of fish/capita/y due to the abundance of fish captured from the Amazon River system. In 1994, Brazil harvested 30,750 t of farmed fresh water fish; 21% of the cultured fresh water fish harvested in all of Latin America and the Caribbean (FAO 1997). Although reliable figures for farmed fresh water fish production in 1996 are not available, estimates range between 40,000 and 50,000 t (Borghetti 1997; Cyrino and Gryschek 1997).

The first species of tilapia introduced to Brazil was *Tilapia rendalli* arriving in São Paulo State in 1953 (Azevedo 1955). Nile tilapia (*Oreochromis niloticus*) and Zanzibar tilapia (*O. urolepis hornorum*) were introduced to Northeast Brazil in 1971 from Ivory Coast, West Africa (Lovshin et al. 1976). Nile tilapia stocks from this introduction have been distributed throughout Brazil. Today, the Ivory Coast strain of Nile tilapia is commonly referred to as “Brazilian” Nile tilapia. Recently, another strain of Nile tilapia was introduced to Brazil from Thailand. The Florida red tilapia hybrid was introduced to Ceará, Brazil in 1981 (M. Picchietti, pers. comm.) and Santos and da Silva (1998) note that at least 5 strains of red tilapia have been introduced to Brazil. The Nile tilapia and a number of red tilapia varieties are widely cultured. Nile tilapia is cultured from within the Amazon River basin in northern Brazil to the most southern Brazilian state of Rio Grande de Sul. Interest in the culture of tilapia has grown rapidly during the past 8 years due to the introduction

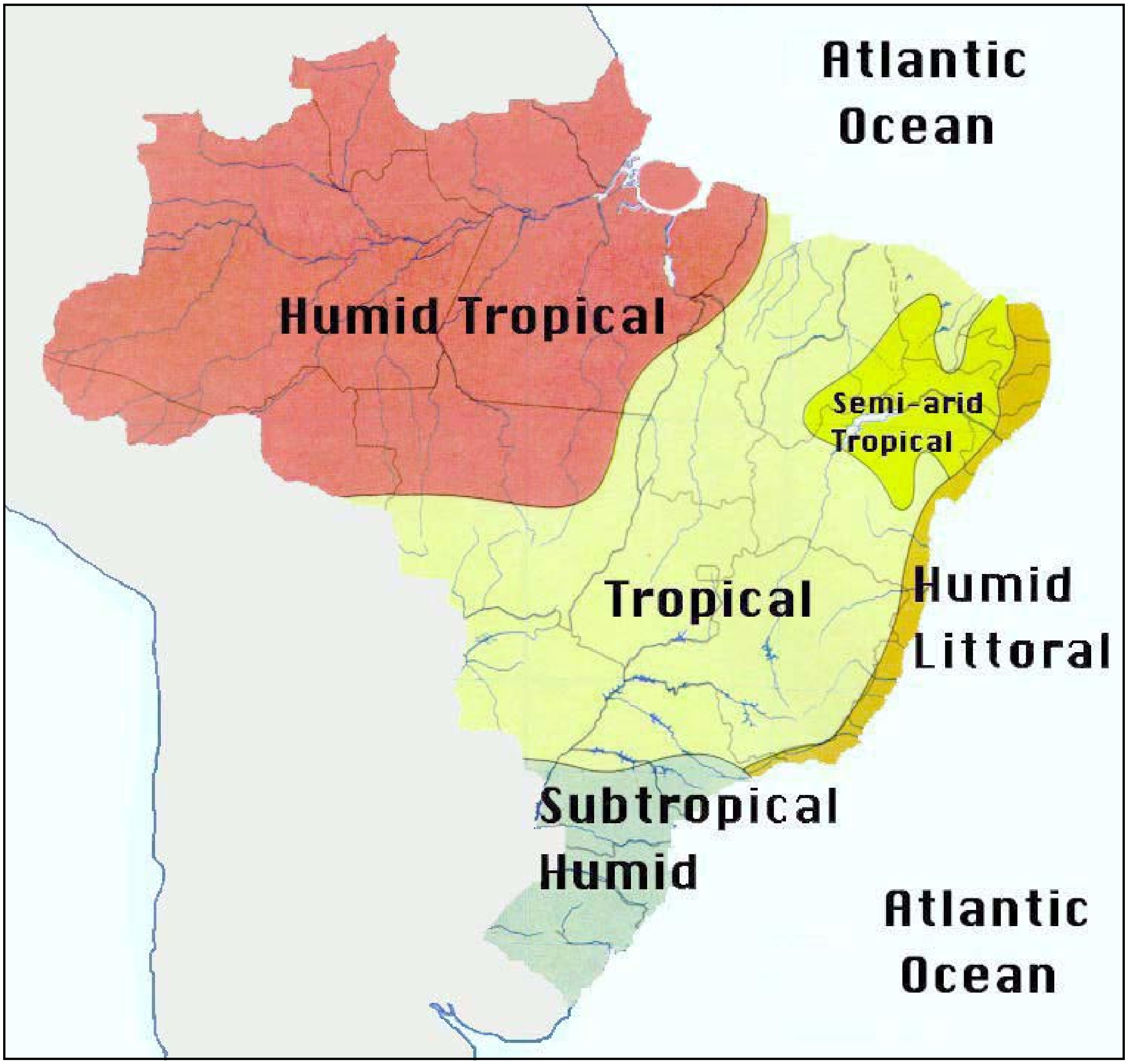
Figure 1. Regional divisions by states within Brazil.



of sex reversal technology to produce all-male populations. The ability to readily sell 400–500 g male tilapia to fee-fishing operations in southern and southeastern Brazil for a high price also encouraged the expansion of tilapia culture. Tilapia are farmed in a variety of systems, including semi-intensive culture in ponds fertilized with animal manures to intensive culture in flowing water raceways and in floating cages. While government statistics are unavailable, this author believes that half of the yearly-farmed fish production in Brazil is tilapia, approximately 20,000–25,000 t. If this harvest total is correct, Brazil has passed Colombia as the leading producer of farmed tilapia in South America.

This chapter will review the importance of tilapia culture within Brazilian fish culture, characterize the methods used to reproduce and culture tilapia, and describe markets for tilapia.

Figure 2. Climatic divisions within Brazil.



CLIMATE

Eighty percent of Brazil has a tropical climate. The most southern Brazilian state of Rio Grande de Sul (RS) and higher elevations in the states of Santa Catarina (SC) and Paraná (PR) have cool subtropical climates (Figures 1 and 2). Low elevations in the states of Santa Catarina and Paraná, and portions of the states of São Paulo (SP), Mato Grosso do Sul (MS), Minas Gerais (MG) and Rio de Janeiro (RJ) have a warm, subtropical climate. Tilapia have an 8–10 mo growing season in the cool subtropical climate. Therefore, states with such a climate must protect tilapia grown outdoors from cold water temperatures during the winter months of May through September. States with a warm subtropical climate have a 2–3 mo winter in June, July and August when a cold front and cloud cover can cause water temperatures to drop below 15°C and kill tilapia in shallow ponds. Tilapia are able to survive the winter in deep ponds or in cages located in large reservoirs in years with normal winter temperatures as long as fish are not stressed by low dissolved oxygen concentration or handling. Water temperatures can warm above 20°C on sunny days during the winter but fish growth remains slow. States with a tropical climate have a 12mo growing season and winterkill of tilapia is of no concern (Simieli 1993; Castagnolli 1995).

FEED MANUFACTURE

Commercially produced pelleted diets manufactured specifically for fish became available in the early 1990s. Presently, 32 factories in Brazil manufacture feeds for fish, shrimp and frogs; most are located in southern and southeastern Brazil. Fish farmers located in west-central, northeastern and northern Brazil must truck fish feeds from the south, increasing the cost considerably. The Brazilian fish feed industry has grown 31% in the last 3 y. Coelho (1997) estimates that 55,000 t of aquaculture feeds were manufactured in 1996, an increase of over 1,300% from 1993. Ninety-two percent of the manufactured aquaculture feeds were for fish. In 1993, all pelleted fish feeds were sinking, but extruded feeds account for 60–70% of the fish feeds produced in 1996 (Coelho 1997). The National Association of Feed Manufacturers forecasted that 80,000 t of fish feed would be produced in 1998.

Pelleted diets are manufactured in a variety of sizes and formulas. Prices for sinking and extruded diets sold in 25 kg bags vary with the manufacturer, diet formulation and distance the diet must be transported. A 32% protein, nutritionally complete, extruded diet cost US$0.38/kg in southeastern Brazil in July, 1998. Only a small amount of fish diets are sold in bulk at this time.

REPRODUCTION

Historical Perspective

The National Department of Works Against the Droughts (DNOCS), a federal Brazilian agency located in northeastern Brazil began to produce mixed-sex Nile tilapia fingerlings in their hatcheries in 1973 for stocking into public and private reservoirs. Adult Nile tilapia were stocked into spawning/nursery ponds at 1 fish/m^2 at a ratio of 3 females to 1 male and allowed to reproduce for a period of 3–6 mo. Fingerlings were removed periodically from spawning ponds and stocked directly into reservoirs. No attempt was made to capture fry from spawning ponds and transfer them to nursery ponds for further growth. Between 1933 and 1982, DNOCS stocked 26.1 million fingerlings comprised of 28 species into public and private reservoirs. Of this total, 53%, or 13.8 million fingerlings were Nile tilapia even though spawning of Nile tilapia in DNOCS hatcheries began only in 1973 (Gurgel 1984). DNOCS biologists began researching the production of all-male hybrid tilapia fingerlings at the Centro de Pesquisas Ictiólogicas located in Pentecoste, Ceará (Lovshin 1982). Male *O. u. hornorum* were crossed with female *O. niloticus* to produce all male offspring. All male fingerlings were distributed to local fish farmers for growth to 400–500 g. Initial success producing market size all-male hybrid tilapia stimulated other public agencies and private farmers within and outside the northeast to purchase Nile and Zanzibar tilapias from DNOCS to begin their own culture programs with all-male hybrid tilapia. However, producing a numerous and consistent supply of all male hybrid tilapia proved difficult. Differences in reproductive behavior of female *O. u. hornorum* and male *O. niloticus* resulted in reduced spawning and the number of offspring produced per spawning period were reduced when compared with fry numbers obtained when each species was spawned separately. Additionally, all male offspring are produced only when pure genetic lines of each species are crossed. Maintaining pure genetic lines of Nile and Zanzibar tilapias over long periods of time proved difficult and less than 100% male offspring often resulted. To further complicate the maintenance of pure genetic lines of Nile and Zanzibar tilapias, the hybrid is fertile and readily backcrosses with females of either species (Lovshin 1982).

Present Practices

Tilapia culture in Brazil made a great leap forward in the late 1980s with the introduction and mastery of techniques to sex reverse tilapia fry. Most tilapia fry are produced by stocking adult tilapia at a ratio of 1 male to 2–3 females into small earthen ponds. Fry are partial harvested by seining the pond margin with a small mesh seine 10–14 d after stocking the brood fish. Partial fry harvests are continued at 2–3 d intervals for a period of 2–3 mo, at which time the pond is drained, the brood fish are transferred to a new spawning pond and the spawning cycle repeated.

Recently, a system for producing tilapia fry developed in Thailand was introduced to Brazil and is slowly growing in popularity (MacIntosh and Little 1995). Adult tilapia are stocked into small mesh screen cages (*hapas*) at a ratio of 1 male to 1 female and 5–7 fish/m^2. Eggs are removed from the mouths of incubating females 5–7 d after stocking the brooders. The fertilized eggs are artificially incubated in plastic jars with a filtered water flow. Male and female brood fish are segregated by sex and rested for 7–10 d before initiating a new spawning cycle.

Fry hatched from artificially incubated eggs are a uniform size and age and can be stocked into units for sex reversal without grading. Tilapia fry removed from ponds by periodic harvest are graded and fry less than 12 mm are stocked into fiberglass troughs, concrete tanks, small mesh screen *hapas* or small earthen ponds for sex reversal. Fry stocking densities range from 1,000–4,000/m^2 depending on amount of water exchange and ability to maintain good water quality throughout the 21–28 d sex reversal period. Fry are fed powdered diets mixed with 60 mg of methyltestosterone/kg of feed. Methyltestosterone can be purchased in Brazil. Commonly, 0.5–1.0 g fry are sold to tilapia growers immediately after sex reversal. Sex reversed tilapia fry are widely available in Brazil and sell for US$40.00–$60.00/1,000 depending on size and quality. A recent issue of a Brazilian aquaculture magazine contained 11 advertisments for producers selling sex reversed Nile and red tilapia fingerlings (Anonymous 1998). Virtually all sex reversed tilapia fingerlings are produced by the private sector.

CULTURE METHODS

Extensive

The "drought polygon" covers close to 1,000,000 km^2 within 9 states in northeast Brazil. This semi-arid region has an unreliable 3–5 mo rainy season followed by a long, harsh dry season. Normal annual rainfall is 400–800 mm but the area is plagued with periodic droughts that last 1–3 y. Historically, droughts caused massive human migrations out of the region because of food and water shortages. The severe climate continues to cause many hardships to the rural population (Araujo 1982).

The Brazilian government created DNOCS in 1909 to combat droughts. The agency constructed earthen dams to capture and store rainfall for use by the population during the dry season (Gurgel 1984). The water has multiple uses including human and livestock consumption, hydroelectric power generation, irrigation, recreation, and fish production. DNOCS realized that the newly impounded water could yield large quantities of fish that would provide impoverished populations with a supply of inexpensive animal protein. Chemical and biological studies of the impounded waters demonstrated that they were rich in minerals and natural foods for fish. However, the native fish fauna was not productive and limited to riverine species that were able to survive long periods of drought. DNOCS concluded that introduction of desirable species would be required to increase fish yields. Starting in 1933, DNOCS biologists tested and stocked species of fresh water fish and shrimp from river basins outside the northeast and exotic to Brazil. Fish were selected for their economic value, ability to reproduce in reservoirs during periods of low rainfall and ability to fill an underutilized ecological niche. (Gurgel 1984; Lovshin et al. 1976).

DNOCS controlled the commercial capture of fishes in 100–103 reservoirs comprising about 150,000 ha of water from 1962 until the early 1990s. *Tilapia rendalli* was introduced to the northeast in 1956 and was the dominant tilapia species captured in DNOCS controlled reservoirs until 1977. *O. niloticus* was introduced into reservoirs in 1973 and surpassed *T. rendalli* in catch by 1977. Maximum annual capture of the *T. rendalli* from DNOCS controlled reservoirs was 1,500 t recorded in 1975. Capture of Nile tilapia peaked in 1980 when 5,850 t were removed from DNOCS controlled reservoirs. Between 1980 and 1990, annual Nile tilapia harvest from DNOCS controlled reservoirs has fluctuated between 4,000 and 5,850 t, representing 30–35% of the total fish capture (DNOCS 1980–1990). Tilapia captured from public and private reservoirs are marketed throughout the northeast and are the principal fresh water fish consumed in the region.

Nile tilapia was never widely stocked into reservoirs in central and southern Brazil because the federal government prohibited the stocking of Nile tilapia into waters outside the northeast. Thus, a capture fishery for tilapia never developed outside of northeastern Brazil.

Semi-Intensive

Research into methods of semi-intensive culture of Nile tilapia was initiated in the early 1970's at the Centro de Pesquisas Ictiológicas. Research evolved around the use of chemical and organic fertilizers and agricultural by-products to grow all male tilapia hybrids in earthen ponds. Tilapia hybrids were stocked at 1/m^2 and grown from 20 g to 200–300 g in 180–240 d. Net yields ranged between 2,000 and 3,000 kg/ha and feed conversion of agricultural by-products to fish averaged 3 to 1 (Lovshin 1982). When stocking rates were increased to 2–3/m^2 and the culture period extended to 1 y, yields were increased to 10,000 kg/ha. Daily applications of fresh pig manure from the equivalent of 120 feeder pigs/

ha of pond surface resulted in a harvest of 2,500 kg of male tilapia/ha in 180 d (Lovshin 1982).

Technology to produce tilapia hybrid fingerlings and grow them to 300–400 g on agricultural by-products and organic fertilizers was disseminated to farmers in northeastern Brazil by DNOCS. A small number of farmers began culturing tilapia hybrids using locally available feeds and fertilizers, but tilapia culture never gained much importance amongst northeastern farmers. Northeastern farmers became disillusioned with semi-intensive tilapia culture because all male hybrid tilapia fingerlings were hard to obtain, a small number of females usually were introduced with the male fingerlings resulting in unwanted tilapia reproduction in the grow out ponds, and the market value was low because of the large quantity of tilapia captured from reservoirs.

Interest in semi-intensive culture of tilapia never expanded outside northeastern Brazil until the late 1980's and early 1990's. Tilapia culture grew in southern and southeastern Brazil with improvement in the method of producing male tilapia fingerlings. Presently, producers in the states of Santa Catarina, Paraná and São Paulo lead Brazil in the harvest of farmed tilapia. Methods of sex reversing tilapia fry to produce 95–98% male fingerlings became widely disseminated among private farmers. Most tilapia are cultured in earthen ponds of less than 1 ha on farms with fewer than 5 ha of water. Use of animal manures to fertilize pond waters is popular in Santa Catarina and Paraná states where the majority of swine raised in Brazil are produced. Ponds stocked with male tilapia in monoculture or in polyculture with common and Chinese carps yield 3,000–4,000 kg/ha/crop when ponds are integrated with pig husbandry. The remainder of Brazil relies almost exclusively on feeds to grow tilapia in ponds. Male tilapia are stocked at 1–3 /m^2 and grown to 400–500 g in 5–8 mo depending on water temperatures (i.e. region). Normal yield ranges from 6,000–8,000 kg/ha/crop but yields as high as 10,000 kg/ha/crop are reported from the northeast of Brazil where climate and water quality are considered ideal. Water exchange of 5–15% of pond volume/d is not unusual. Equipment for determining dissolved oxygen concentration is available but expensive, a condition of little consequence because proper use and interpretation of data are poorly understood by farmers. Thus, control of dissolved oxygen concentration is usually accomplished through water exchange. Mechanical aeration is not widely used by fish farmers as electricity is rarely available at the pond site and aerators are expensive. Yet, as tilapia culture in ponds intensifies, more mechanical aeration will be used instead of water exchange to maintain good water quality conditions due to controls on water use and effluent release by the government.

Misinformation and the lure of higher profits tempt farmers to increase stocking rates to 5–7 tilapia/m^2 in an effort to increase yields. However, these attempts have been associated with slow growth, increased mortality and poor feed conversions, leading to lower profits and often to economic failure.

Intensive

Fish feeds produced in Brazil improved steadily and by 1995, nutritionally complete floating feeds for tilapia were manufactured in southern and southeastern Brazil. Interest in cage culture is expanding rapidly as more information and nutritionally complete floating feeds become available to farmers, and state and federal agencies issue permits for cage culture on public waters. Additionally, start up costs for cage culture are much lower than for pond culture. Cage volumes and stocking densities range from 4 m^3 cages stocked at 200–300 fish/m^3 to cages 100 m^3 or larger stocked at 25–50 fish/m^3. Yields range from 50 kg/m^3 in 100 m^3 cages to 150 kg/m^3 in 4 m^3 cages. Cages in Brazil can not be enclosed with nylon or hard plastic mesh because many wild fish, especially piranha, *Serrasalmus sp.*, easily cut nylon or plastic mesh. Therefore, cages are constructed from galvanized or plastic covered chain-link wire mesh. Currently, the major barriers to rapid expansion of cage culture in Brazil are the cost and inconsistent nutritional quality of extruded feeds.

High land costs in the state of São Paulo have encouraged experimentation with circular and rectangular tanks or plastic lined earthen ponds with daily water exchange or constant water flow (raceways). Circular tanks have a drain located in the center to make removal of settleable solids easier. Mechanical aeration is commonly used in tanks with partial water exchange. Culture systems with pumped and/or gravity flow water supply are found. Male tilapia are commonly stocked at 100–200/m^3 and grown to 400–500 g. Yields range from 50–100 kg/m^3/crop. High construction and operating costs of these intensive culture systems make profitability questionable.

MARKETS AND PROCESSING

Most farmed tilapia are sold live to operators of fee-fishing ponds (Martin et al. 1995). The explosive growth of fee-fishing ponds in the last 3 years in southern and southeastern states has provided tilapia farmers with ready buyers (Martins 1996). The state of São Paulo is estimated to have 1,700 fee-fishing operations (Furtado 1998). These operations range from single ponds with little infrastructure to elaborate, multi-pond complexes with pond-side structures to provide shade for fishers, illumination for night fishing, a restaurant, playground for children and picnic area for families. Pond bank prices that producers receive for live tilapia sold to fee-fishing operators vary from US$1.20–$1.90/kg. The demand for healthy, live tilapia for stocking fee-fishing ponds has stimulated a fish transportation industry. Initial efforts at transporting live tilapia involved crude equipment and little or no information about proper loading rates and hauling techniques, often ending with major fish mortality. Live fish hauling techniques have improved but fish mortality remains a problem due to poor harvest and handling techniques before transport, and the inability of tilapia to withstand harvest and transport stress during winter months with cool water temperatures.

The rapid expansion of fee-fishing operations has forced many of these operations to close permanently. In response to these closures, tilapia farmers are finding alternative markets for their fish. Major food fish markets for tilapia are in the populous southeastern and southern regions, although consumers there are less familiar with tilapia.

Prices paid by food fish consumers and processors are lower than those paid by fee-fishing operations. High profit margins earned by selling fish to fee-fishing operators are evaporating as farmers are forced to sell their tilapia on the food-fish market. Farmers can sell whole tilapia directly to consumers for US$0.90–1.40/kg and to processors for US$0.75–1.10/kg (Anonymous 1995). Nile tilapia is still the tilapia of choice among growers but culture of red tilapia is growing rapidly as producers sell more tilapia to food fish markets.

Processing plants designed to manually clean and freeze 40–50 t of cultured tilapia/wk were constructed in Paraná and Santa Catarina states. Numerous small, family-owned facilities for manually producing small quantities of tilapia fillets for sale locally are in operation. Tilapia weighing 350–500 g are filleted by hand, yielding 56–84 g (2–3 oz) fillets. Pin bones along the lateral line are rarely removed. Tilapia fillets are sold fresh and frozen, often packaged in plastic bags or Styrofoam trays covered with plastic wrap. Tilapia are also frequently sold whole, on ice in neighborhood open markets. In 1997, only 1,300 kg of tilapia fillets were exported to the US (Fitzsimmons 1998).

FUTURE

Brazil has the potential to become a major world supplier of farmed tilapia, primarily because Brazil is one of the few countries in the world with abundant low cost land and water. Most of Brazil has a tropical climate that will permit year around tilapia growth. Brazil is a major producer and exporter of soybeans and corn, grains that form the basis of most fish feeds. Brazil has a large, growing population of consumers that will demand more fish as the availability and quality of fish in the market place improve and as prices decline.

Large earthen pond farms with many hectares of water in regions with tropical climates, abundant water and inexpensive feed grains will become the dominant source of farmed tilapia in Brazil. Presently, farmers in southern and southeastern Brazil produce most farmed tilapia in spite of cool winter water temperatures. However, as the private sector develops feed mills and other infrastructure needed in states with a tropical climate, the major tilapia growing regions will move to west-central and northeastern Brazil. Tilapia culture may be limited in states located in the Amazon River Basin because the federal government is considering legislation that would prohibit tilapia farming within this region. Water inflow will be limited to maintenance of water levels and mechanical aeration will be the major source of dissolved oxygen control. Effluents from ponds will be minimized, reducing the potential for environmental pollution. Cage culture on large hydrelectric reservoirs is likely to become popular and compete favorably with fish raised in earthen ponds if environmental pollution can be controlled.

Intensive culture systems using large quantities of water to flush wastes from culture units are unlikely to be economically competitive with earthen ponds and cages except in situations where low cost gravity-fed water is available. The use of animal manures to fertilize pond waters to improve fish yields will not be widely practiced because Brazil has no tradition of integrated fish culture. Therefore, culture systems based on widely available and reasonably priced pelleted fish feeds will dominate.

Brazil has a large, untapped market for fishery products. Importation of fisheries products has grown 10% annually, and exports decreased from US$12 million–US$2 million in the last 2 y. The rising internal demand for fish suggests that most cultured tilapia will be sold within Brazil in the near future. As tilapia culture in Brazil develops into an industry in the future, Brazil may become a major exporter of farmed tilapia. Eventually we will learn whether the vast potential for tilapia culture in Brazil will result in a sustainable industry supplying tilapia to consumers in Brazil and throughout the world.

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