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Rich Food for Poor People

Genetically Improved Tilapia in the Philippines

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Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at www.ifpri.org/pubs/otherpubs.htm#dp.

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ABSTRACT

The Genetic Improvement of Farmed Tilapia (GIFT) project, which operated from 1988–97, served as a launching point for tilapia improvement efforts in Asia, as well as tropical finfish genetic improvements globally. Based on the selective breeding of Nile tilapia, the GIFT project succeeded in producing tilapia with faster growth rates, higher survival rates, and a shorter harvest time, thus increasing fish yields dramatically. These attributes, along with its stable, low price, have made tilapia an extremely popular food source in Asia, especially among poor consumers. The resounding success of tilapia production was buoyed by strong institutional support from national and international research institutions, regional networks, governments, donors, and small-scale, private actors. Most importantly, a strong initial mandate to apply the GIFT project design to improve aquaculture in general makes GIFT an exciting and replicable benchmark for future food security efforts.

Keywords: Millions Fed, Food Security, Tilapia, Philippines, Genetically Improved, Worldfish, ICLARM

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AFMA	Agriculture and Fisheries Modernization Act
ASEAN	Association of Southeast Asian Nations
BFAR	Bureau of Fisheries and Aquatic Resources
BFAR-NFFTC	Bureau of Fisheries and Aquatic Resources' National Freshwater Fisheries Technology Centre
CGIAR	Consultative Group on International Agricultural Research
DEGITA	Dissemination and Evaluation of Genetically Improved Tilapia
DFID	Department for International Development
FAC-CLSU	Freshwater Aquaculture Center of the Central Luzon State University
FAO	Food and Agriculture Organization of the United Nations
GET EXCEL	Excellent strain that has a Comparative advantage over other tilapia strains for Entrepreneurial Livelihoods projects in support of aquaculture for rural development
GFII	GIFT Foundation International
GIFT	Genetic Improvement of Farmed Tilapia
GMT	Genetically Male Tilapia
GST™	GenoMar Supreme Tilapia
ICLARM	The International Center for Living Aquatic Resources Management
INGA	International Network on Genetics in Aquaculture
PCAMRD	Philippine Council for Aquatic Marine Research and Development
TIDP	Tilapia Industry Development Program
UNDP	United Nations Development Program
UPMSI	Marine Science Institute of the University of the Philippines
USAID	United States Agency for International development

1. INTRODUCTION

The genetic improvement of tilapia is the story of how a coalition of governments, national and international agricultural research centers, regional networks, and private actors worked together to produce an affordable and hardy fish that could meet the needs of the poor. It also represents an achievement for one of the fastest growing food-producing subsectors in the world—aquaculture. Improved tilapia is an example of aquaculture's unique ability to meet projected global demand for fish, and in the process, achieve food security for millions of people around the world.

During the last decade, the overuse of capture fisheries has led to approximately 52 percent of global marine fish stocks becoming fully exploited (FAO 2007). In contrast to the decline of capture fisheries, aquaculture has skyrocketed. From 1950–2004, aquaculture experienced an 8.8 percent annual growth rate, making it the single fastest growing food-producing sector in the last three decades (FAO 2006a, Acosta and Gupta 2009). In 1987, the Food and Agriculture Organization of the United Nations (FAO) estimated aquaculture production (excluding seaweed) to represent a mere 11.1 percent of world fish production; by 1999, this figure had ballooned to 26.2 percent, or more than 32.3 million tons (Ahmed and Lorica 2002). It is projected that over the next decade, the demand for fish will increase by an additional 37 million tons. With such success stories as genetically improved tilapia, aquaculture may be well poised to meet this demand, with a projected contribution of 41 percent of total fish production by 2020 (Delgado et al. 2003). It is estimated that if just 5 percent of the area deemed suitable for aquaculture in Africa were put to use, enough extra fish could be produced to feed the growing population on the continent until 2020 (WorldFish 2007).

Aquaculture represents one of the most important contributions of the developing world toward global food security. Low-income food-deficit countries[1] provide nearly 85 percent of the world's aquaculture production, with 94 percent of all freshwater aquaculture originating in Asia (FAO 2002). In absolute numbers, China stands as the leader in aquaculture, producing more than 34,329,122 tons, representing a 78 percent increase from 1997–2006. Other top producers include India, Vietnam, and Thailand (Table 1).

Table 1. Top aquaculture producers

Country	1997	2006
China	19,315,623	34,429,122
India	1,864,322	3,123,135
Vietnam	322,378	1,657,727
Thailand	539,817	1,385,801
Indonesia	662,547	1,292,899
Bangladesh	485,864	892,049

Source: FAO (2006)

The development and deployment of genetically improved tilapia originating in the Philippines is a major success story in this field. Although the Philippines had a substantial tilapia industry prior to this innovation, the breeding of improved tilapia increased fish yields and kept tilapia affordable for the poor. These achievements are generally attributed to the Genetic Improvement of Farmed Tilapia (GIFT) project, which operated from 1988–97, and served as a launching point for other tilapia improvement efforts in the region, as well as genetic improvement of tropical finfish around the world. While increases in production in the Philippines are not as pronounced as they have been in other countries, the success

[1] Defined by the FAO as developing countries whose annual per capita net income is below $1,395 and whose imports of basic foodstuffs outweigh exports.

story of improved tilapia is most coherent in the Philippines, where institutionalization through the original project occurred quite effectively.

Based on the selective breeding of Nile tilapia, the GIFT project succeeded in producing tilapia that grows faster, has a higher survival rate, and has a shorter harvest time, thus increasing fish yields dramatically (Table 2). These assets have made it an extremely popular fish strain; in 2003, GIFT and GIFT-derived tilapia strains comprised 68 percent of total tilapia seed produced in the country (ADB 2003). Additionally, improved tilapia has demonstrated itself to be a food that is particularly relevant to the poor, due to its stable, low price and its income elasticity of demand among poorer populations. It is currently estimated that 19.3–22.6 million Filipinos have benefited from GIFT and GIFT-derived strains. Gains are not just limited to consumers: approximately 280,000 people in the Philippines benefit directly or indirectly from employment in the tilapia industry, including fish farmers, and hatchery operators (CGIAR 2006). Producing improved strains of tilapia has proven to be a profitable venture for these individuals, costing 32–35 percent less to produce than non-improved strains (Dey 2002) . The internal rate of return of the development and dissemination of GIFT is estimated at more than 70 percent from 1988–2010 (ADB 2006).

Table 2. Impact indicators

Indicator	Output
Individuals affected	19.3-22.6 million
Adoption rate	68%
Internal rate of return	70%
Changes in yields (% and kg/ha)	64% in individual tilapia growth
Changes in food production (% and tons)	186%
Cost savings	32-35%
Increase in consumption	362%
Jobs affected	280,000

The achievements in improved tilapia have generated a lively exchange of ideas, research methodologies, and genetic materials in developing countries across Asia, and amongst scientific institutes, international organizations, and the private sector. A promising model in one country has now been replicated and greatly improved in many others, the whole representing a relevant solution for the food security of the world’s poor. This paper focuses on the background and trajectory of the improved tilapia story, as well as the enabling factors that have made it a success.

2. GLOBAL HISTORY OF TILAPIA

Capture fisheries harvest fish in natural environments while fish culture, or fish farming, is the practice of cultivating fish in a confined water area. The latter is similar to agriculture and livestock farming systems in the sense that it often involves applying organic manures and inorganic fertilizers for the feeding, breeding, and caring for the health of fish (Kumar 1992). Fish culture can generally be divided into four different stages: the production of broodstock, or sexually mature fish; the production of fish eggs; the rearing of juveniles; and, finally, growout, the stage at which fish are readied for market (Box 1). An aquaculture facility, such as a hatchery or fish farm, may include all production stages or focus on just one.

Box 1. Technical terminology

Broodstock: Sexually mature fish.
Dialelle: A mating scheme used by breeders and geneticists that involves crossing parents in order to produce hybrids, thereby giving insight on the genetic quality of certain crosses.
Generation: All of the offspring that are at the same stage of descent from a common ancestor. Generation 9 tilapia, for example, would signify the ninth set of successive offspring resulting from nine cycles of reproduction after the original parents (generation zero).
Grow out: The stage of the life cycle in aquaculture leading to the point at which fish are marketable.
Heterosis: Increase in size, yield, performance, or other favorable traits found in hybrids, relative to the average of the parental lines or strains.
Spawners: Fish that produce young.

Source: Hallauer and Filho (1988); Access Science Encyclopedia Entry (2009).

Tilapia, coming from the Tswana word for fish, *thiape*, is the name of a group of warm water bony fishes originating in Africa and the Middle East's Jordan Valley (Guerrero 2008). The global expansion of tilapia began in earnest in the 1970s but was tempered by a lack of focus on genetics and selective breeding (CGIAR 2006). The then International Center for Living Aquatic Resources Management (ICLARM), now the WorldFish Center, was able to overcome this obstacle thanks to the establishment of an internationally recognized selective breeding program, as will be detailed later in this paper. Through these and other similar efforts, 19 of approximately 100 tilapia species have been cultured or cultivated; of these, the ones that hold the most prominence for aquaculture are the Nile tilapia (*Oreochromis niloticus*), the Mozambique tilapia (*Oreochromis mossambicus*), and the blue tilapia (*Oreochromis aureus*) (Guerrero 2008).

Global tilapia farming until the 1940s was marked by experimental pond cultures in Africa and some commercial activity in Asia. Indonesia used *O. mossambicus* in brackishwater (saltwater) ponds and rice fields, providing protein for its citizens during the Second World War. Experiments on the same culture in Singapore yielded more than 1,300 kilograms per hectare, an early sign of the species' potential for meeting food security needs (Guerrero 2008). The 1950s and 1960s saw the emergence of subsistence-level farming of *O. niloticus* and other species in Nigeria, French Equatorial Africa, and the Cameroon. *O. mossambicus* was brought to the Philippines and the United States, among other countries, and sex-reversal (discussed in detail later in this paper) and sterilization experiments were carried out in Malaysia, Israel, and the United States.

The 1970s was marked by four major developments: the release of hormonal sex reversal technology; the commercialization of tilapia cage culture; the use of *hapas* or floating net enclosures in breeding; and the rise of Taiwan in the commercial hybrid tilapia market (Guerrero 2008). In the 1980s, tilapia farming exploded in Southeast Asia, with three international conferences on tilapia, the commercialization of hormonal sex reversal technology, the development of breeding technologies for *O. niloticus,* and the emergence of the Philippines as the largest tilapia-producing country in the world (Guerrero 2008).

The 1990s established tilapia farming's important role in world aquaculture: tilapia demand skyrocketed in the United States, industrial farming emerged in Africa and South America, and, per the focus of this paper, widespread genetic improvements to *O. niloticus* were made (Guerrero 2008).

Today, tilapia is one of the top ten fish species that contributes more than 1 million metric tons to global fish production (Guerrero 2008). A total of 1,166,737 metric tons of total tilapia production is sourced from the Association of Southeast Asian Nations (ASEAN) (Bartley et al. 2004). This figure, however, is widely believed to be an underestimate because many tilapia-farming countries do not report their production to the FAO (FAO 2009). Additionally, an untold amount is consumed within producer households, never entering market chains.

3. AQUACULTURE IN THE PHILIPPINES

In 2000, the Philippines' fisheries sector employed more than 1 million people, or 12 percent of the total rural labor force (Garcia, Dey, and Navarez 2005). It is divided into aquaculture and capture fisheries, the latter which is in turn divided into commercial and municipal fishing. From 1997–2003, commercial and municipal capture fishing experienced low growth rates, 4 and 2 percent respectively, due to dwindling fish resources. Aquaculture, conversely, saw an 8 percent production surge during this same period (Garcia, Dey, and Navarez 2005).

That aquaculture has taken off in the Philippines can be attributed to two main factors. First, environmental degradation has necessitated such development. A study of nine Asian countries, of which Philippines was one, concluded that inshore demersal fish (or bottom feeders) stocks declined by up to 44 percent since the 1970s (Silvestre et al. 2003). Faced with the depletion of fishery resources and population growth, aquaculture has been framed as a sustainable alternative to traditional capture fisheries (Acosta et al. 2006). Second, fish are an integral part of the national diet of the Philippines: the average Filipino consumes 28 kilograms of fish every year, as compared to the world average of 16 kilograms (FAOSTAT 2009). Thus, the demand for a reliable source of fish constantly drives new technologies that can raise yields and meet the nutritional demands of a growing population. Aquaculture now comprises 40 percent of the national fisheries sector (Garcia, Dey, and Navarez 2005). The FAO estimated 1998 production to be 72,000 tons; 2007 production stood at 2,214,826 tons (CountrySTAT Philippines 2009).

While national consumption of fish and fishery products stood at 2.3 million metric tons per year during 1997–2001, production still averaged only 2.2 million metric tons during that same period (Garcia, Dey, and Navarez 2005). A total of 100,000 metric tons of imports filled the remaining consumption-production gap. Still, the country is a net fish exporter and as of 2001, fishery products contributed to 3.7 percent of its gross domestic product.

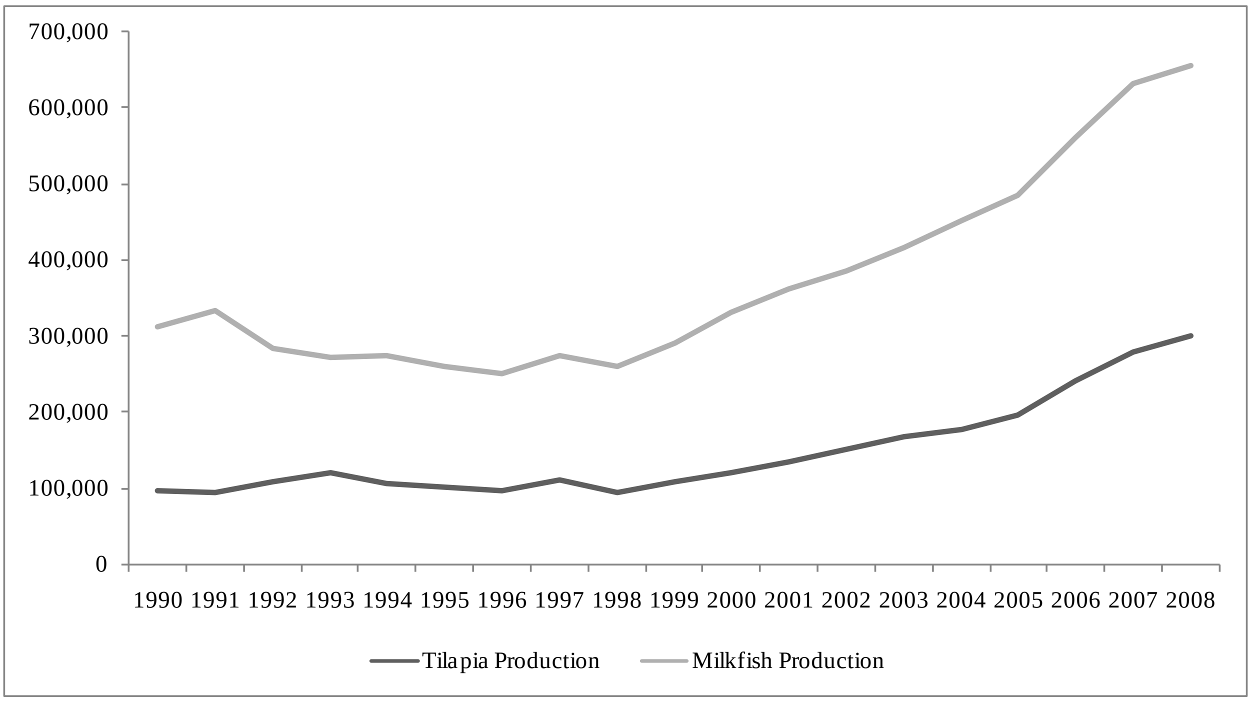
The Philippines farms freshwater fish in ponds or cages, and these two methods have differing characteristics. For example, while ponds boast an average area of 4.91 hectares, cages have an average size of 1.26 hectares. This difference does not necessarily mean that cage operations are more closely tied to smallholders than pond operations, i.e. that the size of an operator is an indicator of wealth. A very small cage farm, for example, can very often be managed with industrial level inputs, thus making it only accessible to farmers with high levels of capital. In 1995-96, 75-99 percent of pond and cage farms were owned, rather than rented, and 71-87 percent were privately operated. Ponds offered net returns of US$853 per unit area, while cages offered $263 (Dey et al. 2000b). [2]

[22] All $ are U.S. dollars unless otherwise noted.

4. TILAPIA BREEDING IN THE PHILIPPINES

Tilapia is the main freshwater fish species cultured in the Philippines, comprising 63 percent of the total freshwater aquaculture production in 2000 (Dey et al. 2005). Though it is still easily rivaled by the traditional milkfish (Graph 1), the latter is raised mostly in brackishwater environments, leaving tilapia as the leader in freshwater cultivation.

Graph 1. Milkfish and tilapia production, 1990-2008



Source: Philippines' Bureau of Agricultural Statistics

In general, tilapia is considered to be so versatile across different environments that it has been dubbed the "aquatic chicken" (Acosta and Gupta 2009). Throughout the country, tilapia is reared in freshwater or brackishwater ponds or cages, and the practice is characterized as being extensive or semi-intensive within a monoculture system of farming (Box 2). Fish farming does occur with some integration with other activities, such as rice farming (Guerrero 1994). Although other countries in mainland Southeast Asia have recently started the shift to monoculture, stand-alone fish culture has always been the tradition in the Philippines (Guerrero 1996). Compared to other countries, the method has returned low production yields (3,599 kg/ha) but these had a comparatively higher value of $3,421 kg/ha (Eknath and Acosta, 1998).

Box 2. Definitions for common fish culture methods

Monoculture: The practice of cultivating only one fish species in one pond.
Extensive culture: Low intensity aquaculture, such as in ponds as practiced by subsistence farmers. No nutritional inputs, such as manure or feed, are given to the fish, which rely solely on natural food produced in the pond. Yields low fish production.
Semi Intensive culture: A culture that is based on the use of fertilization (manure) and supplementary feed. Yields moderate fish production.
Intensive culture: A practice whereby all nutritional fish requirements are met by formulated feed. The replenishment, aeration, or recirculation of pond water is a component as well. Yields high fish production.

Source: Rahman, Varga, and Chowdhury (1992)

Freshwater ponds, located mostly in central Luzon region, account for approximately 50 percent of tilapia production, while cage culture, mostly associated with southern Luzon region, represents 36 percent of production. Brackishwater culture accounts for the remainder (Guerrero 1996). Tilapia that are grown in cages have an average size of 175 grams while those reared in ponds weigh 130 grams (Dey et al. 2000b). Small-scale private hatcheries produce the majority of tilapia seed, with the supply of fingerlings estimated at 600 million in 1996 (Guerrero 1996).

The history of tilapia farming in the Philippines began in the 1950s, when *O. mossambicus* was introduced from Thailand. Publicized as a wonder fish capable of addressing the low supply of animal protein in the region, the Mozambique tilapia was seemingly easy and affordable to breed (Guerrero 1994, Ling 1977). In the next decade, however, various significant obstacles to the strain's anticipated role in fish farming emerged. Firstly, the batch of *O. mossambicus* that came to the Philippines from Thailand in 1949 had only four survivors: three males and one female (Lowe-McConnell 2000, Pillay 2004). This meant that the genetic basis for all subsequent batches was very narrow, leading to problems associated with inbreeding. The strain also reproduced quickly, resulting in overcrowding and stunted growth in ponds. Its tolerance of salt, as well as its inclination for escaping, made it an invasive fish in brackishwater ponds. It is reported, for example, to have caused the near extinction of local *Mistichthys luzonensis* populations (Yap, Baluyot, and Pavico 1983). Finally, consumers did not accept the dark color and small size of the Mozambique tilapia, making it unmarketable (Guerrero 1994). Due to these shortcomings, interest level in tilapia farming waned and was not revived until a decade later.

In 1974, the Government of the Philippines launched a two-year research program at the Freshwater Aquaculture Center of the Central Luzon State University (FAC-CLSU) (Guerrero 1994). Based on early research showing that male tilapia can grow faster than females, the program focused on monosex male culture and sex reversal of females through fry hormone treatment. This discovery marked the beginning of a line of technologies suited for commercial tilapia production that would be developed over the next few decades. Alongside breeding techniques, other technologies included floating net enclosures for breeding and floating cages with feeding. Upon development, the Government of the Philippines transferred the finished products to both resource-poor rural communities and potential large-scale commercial farmers via three main programs (Table 3) (Guerrero 1994).

Table 3. Programs with a focus on technology transfer to small scale farmers, Philippines

Project	Timeframe	Partners
Inland Fisheries Project	1971–76	FAC-CLSU; Brackish Water Aquaculture Center of the University of the Philippines; National Science Development Board; USAID
Freshwater Fisheries Development Project	1979–83	Bureau of Fisheries and Aquatic Resources; USAID
National Self-Reliance Movement	1980s	Ministry of Human Settlement

Source: Guerrero (1994)

These programs provided farmers with technical assistance via technology demonstrations, extension agents, province-wide workshops, and opportunities for collaboration with researchers. Poor, rural tilapia farmers working with ponds, cages, and paddy fields were also given bank credit for the first time, thus enabling them to access tilapia technologies (Guerrero 1994). Efforts to reach the commercial sector, on the other hand, included utilizing private corporations to pilot technology; offering financing and credit through development banks; and providing incentives to farmer nongovernmental organizations and cooperatives for the adoption of new technology (Guerrero 1994).

Meanwhile, an entirely different strain, Nile tilapia, received its first introduction to the Philippines. Native to Africa, Nile tilapia (*O. niloticus*) was introduced to Asian countries in the 1970s for the purpose of expanding small-scale aquaculture (Gupta and Acosta 2004). Even though it showed promise, issues of insufficient fish seed supply, stagnant production, and poor fish growth began to plague Nile tilapia farmers (Pullin 1980). Two possible causes were linked to this development. Some claimed that the Nile tilapia strain introduced to Asia descended from a small number of fish, which had led to inbreeding and the proliferation of undesirable genetic traits (Pullin and Capili 1988). Others reported that the decline in Nile tilapia could be attributed to unintentional hybridization caused by escaped Mozambique tilapia entering ponds and breeding with imported farmed strains of Nile tilapia. Purportedly, this reduced the productivity and marketability of these latter strains (Taniguchi et al. 1984; Macaranas et al. 1995).

5. THE GENETIC IMPROVEMENT OF FARMED TILAPIA (GIFT) PROJECT

In 1988, the Genetic Improvement of Farmed Tilapia (GIFT) project was launched as a starting point for tropical finfish genetic improvement around the world (Gupta and Acosta 2004). While part of the impetus of the project was rooted in dissatisfaction surrounding previously introduced strains of tilapia, the real aim of the initiative was to build capacity for genetic breeding by supporting national breeding programs with a high quality, heterogeneous base stock of fish. The project involved a range of various partners, including ICLARM, the Norwegian Institute of Aquaculture Research (AKVAFORSK) and the Philippine national fisheries bureaus and centers, including the Bureau of Fisheries and Aquatic Resources (BFAR), the previously mentioned FAC-CLSU, and the Marine Science Institute of the University of the Philippines (UPMSI). On the donor side, the project was jointly funded by the United Nations Development Program (UNDP) and the Asian Development Bank (ADB) (El-Sayed 2006). The methodology for GIFT was based on the success of selective breeding programs for salmon and trout established in Norway in the 1970s.[3]

Phase 1: Finding the Right Fit

The project began by comparing the performance of existing Asian *niloticus* farmed strains and imported wild fish grown communally in 11 different environments representative of Philippine aquaculture (Eknath et al. 1993). The imported strains were collected from Africa, or more specifically, Ghana, Egypt, Kenya, and Senegal, and then transferred to the Philippines. The existing farmed strains collected domestically from the Philippines had been used by tilapia farmers in Asia, though even these strains were originally sourced from Africa as well (Table 4).

Table 4. Origins of Nile tilapia germplasm collected for GIFT trials

Strain	Origin	Date Collected
Egyptian	Egypt	May 1988; August 1989
Ghanaian	Ghana	October 1988
Kenyan	Kenya	August 1989
Senegalese	Senegal	October 1988
Israeli	Ghana	--
Singaporean	Ghana	--
Thai	Egypt	--
Taiwanese	Ghana	--

Source: Eknath et al. (1993)

In the first GIFT experiment, the wild strains in general outperformed the farmed *O. niloticus* strains (with the exception of the Ghana tilapia). Additionally, the Egyptian Nile and Kenyan Rift Valley strains outperformed the West African strains in most test environments. A second experiment, which evaluated fish from a complete 8x8 diallele in eight different environments, confirmed these same results (Bentsen et al. 1998). While the latter study showed that a hybrid between the Egyptian and Kenyan strains would represent a 10 percent improvement over the best pure strain, the logistics associated with a crossbreeding approach were expected to be challenging. Thus, ICLARM scientists pursued selective breeding with the expectation that it would improve tilapia performance better than a crossbreeding program within a few generations (Longalong, Eknath, and Bentsen 1999). More specifically, *O. niloticus* was chosen for its short generation time, ability to tolerate shallow and turbid waters, high

[3] The genetically improved stocks that resulted from the Norwegian programs now account for over 80 percent of the salmon produced in Norway, which is the world's top producer of Atlantic salmon.

disease resistance, and flexibility for fish culture in many different farming systems (Pullin 1983; Pullin 1985; Eknath 1995; Gupta and Acosta 2001). Thus, the expectation that GIFT fish would be distributed throughout the region was woven into the original project design.

Scientists constructed a synthetic base population from the 25 best-performing wild and farmed strains experimented with earlier. By 1993, three generations of selection had been completed and preliminary results showed the selected fish growing much faster than local tilapia strains and survival rates being considerably higher (Longalong, Eknath, and Bentsen 1999). Tilapia farmers were included as stakeholders in on-farm experiments, which were generally successful (Acosta and Gupta 2009).

Based on successive selective breeding rounds of *O. niloticus,* the GIFT project eventually yielded genetic improvements of 7.1 percent genetic change over nine generations of fish, or a 64 percent cumulative increase in tilapia growth over the base population (Ponzoni et al. 2008). It should be noted that higher figures have been reported, such as Eknath and Acosta (1998), who reported a 12–17 percent improvement over five generations of fish, or a 60-85 percent cumulative increase. Conversely, as shown later in the paper, comparisons have shown the GIFT performance advantage to be lower over non-GIFT strains. These studies merely make the point that comparisons between strains can only be interpreted contextually, and will differ across time, location, and farming system (ADB 2006).

The first selective breeding program designed for *O. niloticus* at both the national and international level, GIFT succeeded in overcoming many of the obstacles faced by previous improvement programs for this species (Eknath et al. 1991, 1993). There has been a variety of other GIFT-derived tilapia strains released within the Philippines, as well as complementary genetic improvement technologies. In terms of improved strains, GET EXCEL, for example, was developed in 2000 by the Government of the Philippines by combining an improved strain of Nile tilapia with a rotational mating scheme (Tayamen and Abella 2004). GET EXCEL 2002 was formulated two years later by BFAR's National Freshwater Fisheries Technology Centre (BFAR-NFFTC), which combined strain crosses (such as those from the GIFT, Egypt, and Kenya strains) with rotational mating. Preliminary results have shown this strain to grow faster and have better chances for surviving over other improved market Nile tilapia strains. This prompted the government-led "Nationwide Dissemination of GET EXCEL Tilapia," which seeks to replace old tilapia strains with improved ones (El-Sayed 2006). The GET EXCEL acronym stands for "EXcellent strain that has a Comparative advantage over other tilapia strains for Entrepreneurial Livelihoods projects in support of aquaculture for rural development" (Tayamen 2004). Yet another strain, the FaST strain, was actually developed prior to the release of GIFT, in 1993, as a product of within family selection (based on body weight) of *O. niloticus* in a rotational mating scheme (Tayamen and Abella 2004).

Alongside the selective breeding technologies showcased through GIFT and GIFT-derived initiatives, other genetic improvements to tilapia have taken place in the Philippines. These mainly involve producing all-male tilapia cultures. Tilapia farmers prefer these types of cultures because males are known to grow faster than females, and because such a culture addresses the proclivity of tilapia to excessively reproduce (El-Sayed 2006).

The first of these all-male methods is sex reversal from female to male (Box 3). At least 10 hatcheries currently produce sex-reversed tilapia, accounting for approximately 15 percent of fingerling supply (Mair et al. 2002). However, many of these hatcheries have not yet succeeded in producing cultures with a more than 95 percent male population, the level at which the culture can truly be deemed "all male." Sex ratios currently hover at lower than 90 percent with future improvements seeming unlikely (Mair and van Dam 1996, Mair et al. 2002).

The YY male method, related to Genetically Male Tilapia (GMT), was developed as an alternative to sex reversal technology and involves combining hormonal feminization and progeny (offspring) testing to breed YY male genotypes, which then produce male tilapia when bred with normal females. The technology has been shown to produce a sex ratio greater than 95 percent in controlled environments, with increased yields of 30-40 percent compared to normal mixed-sex tilapia (Mair et al. 1995). The inability of hatcheries to produce their own YY males has necessitated a network that can deliver fingerlings to growers each production cycle. This particular role has been filled by Phil-Fishgen, a dissemination organization under FAC-CLSU, which awards accreditation to qualified hatcheries (Mair et al. 2002).

Box 3. Overview of culture technologies

DNA Fingerprinting: A technique by which a set of polymorphic markers can be simultaneously detected, resulting in a DNA pattern that can identify a unique species, strain, or individual fish. In selective breeding programs, it is used to determine parentage.
Rotational Mating Scheme: A way of structuring mating so as to avoid in-breeding.
Selective Breeding: The process of choosing the parents of the next generation in breeding animals and plants in such a way that it will result in improved performance for certain traits considered to be important during production and marketing.
Sex reversal: The practice of, most commonly, converting female fish to male fish through the use of hormones.
YY male technology: The method of combining hormonal feminization and offspring testing to breed YY male genotypes, which then produce males when bred with normal females.

Source: Zheng and Tang (1993)

There are several drawbacks associated with "all male" production methods. First, injecting tilapia with hormones clearly raises food safety concerns among consumers. Second, regarding YY male technology, producing YY males takes three generations of breeding, meaning that males will be lagging behind genetically, even by as much as 20 to 45 percent, by the time they are ready for use (Ponzoni et al. 2008). Third, the technology requires a high level of sophistication with advanced laboratory facilities, a less than ideal situation for many developing countries. Finally, the dissemination of fingerlings is a mainly passive process, with the beneficiaries being limited to the location of accredited hatcheries, currently only numbering 32 (Mair et al. 2002).

Phase 2: Sharing the Wealth

Having met the first two official objectives of the GIFT project (develop methods for genetically improving Nile tilapia and finfish), WorldFish turned its attention to broader goals. These included dissemination of the GIFT strain; capacity building of national institutions in aquaculture genetics research; genetic, socioeconomic, and environmental evaluation of GIFT; and the facilitation of national tilapia breeding projects (Eknath 1995).

In the Philippines, throughout the life of the GIFT project, GIFT fish were disseminated to farmers through government agencies. The leading agencies responsible for national dissemination included BFAR and FAC-CLSU (Tayamen, Abella and Sevilleja 2006). BFAR established the Program for Fish Varietal Regeneration, which was further subdivided into two programs. The first was the Tilapia Industry Development Program (TIDP), established to upgrade the production capacity of hatcheries affiliated with the Philippine Department of Agriculture through staff training and capital improvements. The second subprogram was the National Tilapia Breeding Program, whose mission was to sustain the genetic advances previously made through research, and to create a wide, national distribution network for improved tilapia strains. NFFTC-BFAR was able to disseminate 553,350 GIFT seed (fertilized fish eggs) to 13 regional outreach stations by the end of 1997 (ADB 2006). In 2003, these same outreach stations received 663,000 GET EXCEL broodstock. An additional 311 hatcheries affiliated with NFFTC-BFAR received 4.2 million fingerlings, while 405 private hatcheries received 5.9 million fingerlings (ADB 2006).

In 1990, the Philippine Council for Aquatic Marine Research and Development (PCAMRD) established the National Tilapia Production Program to further promote tilapia genetic breeding and to distribute improved fish strains to farmers. Under this program, the Tilapia Broodstock Center specifically sought to achieve these goals (Sevilleja 2007).

To fulfill the mandate of tilapia improvement outside of the Philippines, in 1993, the UNDP provided $65,000 to the WorldFish Center to establish the International Network on Genetics in Aquaculture (INGA), as a forum for the exchange of ideas, research methodology, and genetic materials (CGIAR 2006). Based in Penang, Malaysia, INGA boasts 12 developing country members across Asia and Africa; 12 scientific institutes; 4 regional or international organizations; and 1 private sector institution (ADB 2006). From 1994–2003, INGA facilitated 70,913 transfers of GIFT germplasm amongst member countries (ADB 2006). The network has also focused much on capacity building in breeding and genetics in developing countries. As of 2004, 210 participants representing 14 Asian, African, and Latin American countries had been trained under INGA's programs (Acosta and Gupta 2009). Due to funding woes faced by INGA, the WorldFish Center and its partners have partially taken over some of these activities, including helping countries draft national action plans for genetic improvement and dissemination of genetically improved strains (Acosta and Gupta 2009).

In 1992, amidst worries over biosafety and the capacity of many countries to embark on the widespread dissemination of an improved strain, a meeting on International Concerns in the Use of Aquatic Germplasm was held (Eknath 1995). Experts agreed that INGA and the WorldFish Center should transfer GIFT fish in a very careful way, adhering to standards set forth by relevant international bodies like the FAO. It was deemed that any country wishing to import new fish species would be required to sign a Material Transfer Agreement, which deemed, among other things, that countries abide by the Convention on Biological Diversity (CBD) and International Codes of Transfer of Germplasm; limit distribution to areas that could experience negative environmental impacts; not seek intellectual property rights over the germplasm; and ensure that institutions receiving germplasm further down the chain abided by these same rules (Acosta and Gupta 2009).

In 1994, improved tilapia strains were first disseminated through trials conducted at stations and farm environments within five member countries (Philippines, Bangladesh, China, Thailand, and Vietnam) (Acosta and Gupta 2009). Performance evaluations showed Generation 3 GIFT fish consistently outperforming non-GIFT species. In Bangladesh, for example, GIFT strains showed a 78 percent increase in yield gain (Table 5). In China, these same strains exhibited a 3.3 percent increase in survival rates as compared to non-GIFT strains (Dey et al. 2000b). Following other performance evaluations, 133,494 tilapia germplasm were transferred to national agricultural research centers throughout Asia for use in research, breeding, multiplication, and later dissemination to farmers (ADB 2006).

Table 5. GIFT and non-GIFT yields in on-farm trials in select Asian countries

Country	Production system	Non-GIFT strain yield (kg/ha)	GIFT strain yield (kg/ha)	Yield gain (%)
Bangladesh	Pond	896	1,593	78
China	Cage	310,967	389,346	25
	Pond	4,275	4,645	9
Philippines	Cage	15,285	23,551	54
	Pond	912	1,361	49
Thailand	Pond	2,044	2,829	38
Vietnam	Pond	558	743	33

Source: Dey et al. (2000a)

As a caveat, GIFT strains do not uniformly show such spectacular results as conveyed above. For example, Dan and Little (2000) showed that while GIFT fish obtained a significantly larger individual size in cage and pond environments at final harvest than competing Thai or Viet strains, the growth difference is less pronounced. In certain instances, such as among monosex new season-fry in cages, GIFT fish only marginally beat out comparable Thai and Viet strains. However, Ponzoni et al. (2005)

reported that even after a few generations of selective breeding, the population still has additive genetic variance that will allow it to improve even further.

At the close of the GIFT project in 1997, genetic material from the ninth generation of improved tilapia was provided to institutional partners for primarily non-commercial use (Acosta et al. 2006). Donor support for the project ended in the same year, and the public sector was charged with finding a way to continue both breeding and outreach efforts (Acosta et al. 2006). A nonprofit private foundation called the GIFT Foundation International (GFII) was thus established and set about forming seed production partnerships with private-sector hatcheries throughout the Philippines (Acosta et al. 2006). Privately owned hatcheries that were able to meet a certain set of requirements were invited to enter hatchery agreements with GFII, the terms of which included the payment of a licensing fee and research and development contribution; agreement to undergo training; as well as various other marketing and pricing guidelines (Rodriguez 2006). The agreements with GFII were not only intended to streamline the production of GIFT and GIFT-derived strains of tilapia, but also to provide the foundation with a steady revenue stream. In its initial year, GFII entered into partnerships with seven hatcheries, this number remaining a constant for the duration of the contracts. While the foundation was disappointed by the small number of hatcheries that had applied, it eventually came to the realization that only a small number of hatcheries was needed to sufficiently supply the industry (Rodriguez 2006). Indeed, by the end of 2001, it had disseminated 522,700 GIFT broodstock to these accredited hatcheries (ADB 2006).

Surveys conducted with growout farmers and hatchery operators shortly after the transfer revealed that while farmers obtained genetically improved tilapia products from the same stock, and that these were consistently available, the majority of farmers got technical advice from suppliers of the improved strain, rather than extension agents, thereby revealing a weak improved tilapia extension system. Farmers reported that major improved tilapia actors focused on sales of fingerlings rather than the areas where farmers needed technical assistance such as fish breeding, nutrition, fish health, and water quality (Acosta et al. 2006). Thus, while WorldFish and its partners were relatively successful in the *development* of technologies, the *transfer* of these technologies remained a weakness of the overall tilapia improvement efforts. Cooperation among research organizations, local government offices and farmers in dissemination and follow-up were reported to be weak (Acosta et al. 2006).

In 2000, WorldFish received a sample of 60 families of the ninth generation GIFT strain. It distributed these historical strains to its partners in 11 countries in Asia (Gupta and Acosta 2004).[4] The 11 recipients established national breeding programs for the further improvement and dissemination of GIFT fish. Vietnam, for one, has produced and disseminated almost 2 million improved tilapia seed, while hatcheries in Thailand produce and disseminate 200 million GIFT fry on an annual basis. WorldFish continues selection work in Malaysia on the ninth generation GIFT, in collaboration with the national Department of Fisheries (Gupta and Acosta 2004). Current efforts are underway to improve the national breeding programs' activities on genetic improvement and dissemination. In recent years, the WorldFish Center has convened a regional workshop on the subject, conducted a formal inventory of GIFT fish, and published a training manual for those wishing to start or strengthen selective breeding programs (Acosta and Gupta 2009).

Phase 3: The Uncharted Territory of Public-Private Partnerships

In 1999, seeking to expand its market and improve its earnings, GFII entered into an agreement with GenoMar, a private Norwegian biotechnology company, thus marking the first entry of a foreign private entity into the story of improved tilapia (Acosta et al. 2006). GFII transferred dissemination rights to GenoMar, which in turn rebranded the strain as GenoMar Supreme Tilapia (GST™). GST™ is currently disseminated through GenoMar's private hatcheries in the Philippines and China. In the Philippines, 30 million fingerlings are produced annually, while China boasts a production of approximately 280 million.

[4] These eleven countries are: Bangladesh, PR China, Fiji, India, Indonesia, Lao PDR, Malaysia, Sri Lanka, Papua New Guinea, Thailand, and Vietnam.

Dissemination in Asia, Africa, and South America occurs through GenoMar's partner hatcheries (Genomar 2009).

GST™ is currently marketed as having DNA fingerprinting for the genetic tagging of fish, which makes it easier to identify the strains with the optimal characteristics, and a revolving mating scheme, which allows a generation to be completed after only nine monthly batches (Gjoen 2004). According to the biotechnology company, it has created a tilapia strain with a high salt tolerance, rapid growth rate, high feed conversion efficiency, and improved disease resistance. GST™ is estimated to have an average genetic gain of 20 percent with every generation, representing a 35 percent increase over conventional breeding methods (GenoMar 2009). GenoMar produces a new generation of GST™ every nine months; in China, experiments show the strain to have grown more than twice as fast as local strains (Acosta and Gupta 2009). It should be noted that many of GenoMar's claims regarding genetic improvement are controversial. Some critics within the scientific community charge that GenoMar's results are not openly published and as such, cannot be verified (*email communication*). For example, the genetic gains claimed by GenoMar have been achieved in a short time compared with the usual lengthy selective breeding process, pointing to the need for additional independent verification of these results.

The topic of public-private partnerships in fisheries is one that is still relatively new, as compared to the much-studied role of private actors in the crop sector. As dissemination and research has widened across countries and regions, many public institutions have found it integral to involve the private sector. The nature of the public-private partnership between GFII and Genomar opens up a host of issues, the most prominent of these being the private ownership and dissemination of public goods. Genomar, as a for-profit private sector company, holds exclusive commercial rights to GST™ and all subsequent products created from the Generation 10 GIFT strain (Acosta et al. 2006). For example, as of 2003, GenoMar was developing the 14th generation of GIFT-derived strains while WorldFish still only had access to 9th generation strains (GAIN 2003). Thus, while WorldFish continues to keep the 9th generation GIFT fish within the public domain, providing it to governments conducting research and development activities, subsequent versions of the improved tilapia are privately held. What is more, GIFT/GST™ is commercially distributed in the Philippines solely through private channels (Table 6) (Tayamen, Avella, and Sevilleja 2006).

Table 6. Ownership and distribution of improved tilapia in the Philippines

Strain	Breeding nucleus ownership	Distribution channel
GIFT/GST	Private	Private
GET EXCEL	Public	Public-private
YY male	Public	Public-private
FaST	Public	Public-private

Source: Sevilleja (2006)

This issue implies that the poverty focus that was the original objective of the GIFT project may have suffered from a shift from public sector to private sector control. Acosta et al. (2006) point out that the public and private actors involved in improved tilapia breeding have different goals. For example, while public sector GIFT activities had identified their clients as small scale, subsistence-level farmers, the private sector GenoMar focused on medium to large-scale farmers. While the evidence surrounding this claim is uncertain, the relevance and marketability of GIFT strains to the ultimate end users is a serious concern (Sevilleja 2006).

Outside of the GenoMar issue, another problem plaguing public-private partnerships in the Philippines is a general lack of coordination between private and government actors. The improved tilapia industry suffers from a poor delivery of technical assistance to farmers because there is a lack of clear roles for different actors in breeding and dissemination. Private hatcheries, for example, find it difficult to compete with government-run breeding centers and hatcheries due to the latter's seemingly boundless resources and infrastructure (Tayamen, Abella, and Sevilleja 2006). The complexity of these issues limits the establishment of such partnerships, thus stalling potential advances in improved tilapia.

Such an analysis should not be interpreted to mean that public-private partnerships cannot be conducive to the development of the tilapia industry. On the contrary, with preparation, public-private partnerships can dramatically enhance the capacity of an innovation to reach new clientele and become financially sustainable. Specific initiatives can be undertaken to create enabling environments for strategic, win-win public-private partnerships in the improved tilapia sector. These include ensuring that public sector institutions have legal protections when it comes to ownership of improved germplasm; involving the private sector in dissemination in a gradual and thoughtful way; and defining the roles of public and private actors through sound policies (Acosta et al. 2006).

The Philippines has already taken some of these steps. In 2002, private and public stakeholders established the Tilapia Science Center in 2002, which convenes a bi-annual National Tilapia Congress to foster collaboration efforts amongst key players (ADB 2006). The Department of Agriculture through BFAR has also led the establishment of the Tilapia Council of the Philippines to coordinate the different programs under the fishery sector that seek to improve the tilapia industry (Sevilleja 2007). Finally, a Workshop on Public-Private Partnerships for the Delivery of Tilapia Genetic Research Outputs to Philippine End Users produced the Angeles Declaration, which puts forth specific policy recommendations on the ways in which the private sector can complement the industry.

Monitoring and Evaluation

The Dissemination and Evaluation of Genetically Improved Tilapia (DEGITA) was an extension of the GIFT project, which helped national partners introduce the GIFT strain into their local fish stocks. Funded by the ADB, WorldFish, and five participating countries, the project aimed to evaluate the biological, socioeconomic, and ecological nuances of GIFT strain production; assess the impact of the strain on different income groups; and distribute the strain to smallholders (CGIAR 2006). Much of the impact data on GIFT and other genetically improved tilapia is sourced from DEGITA studies, helping partners over time tailor improve and strengthen their research and outreach activities.

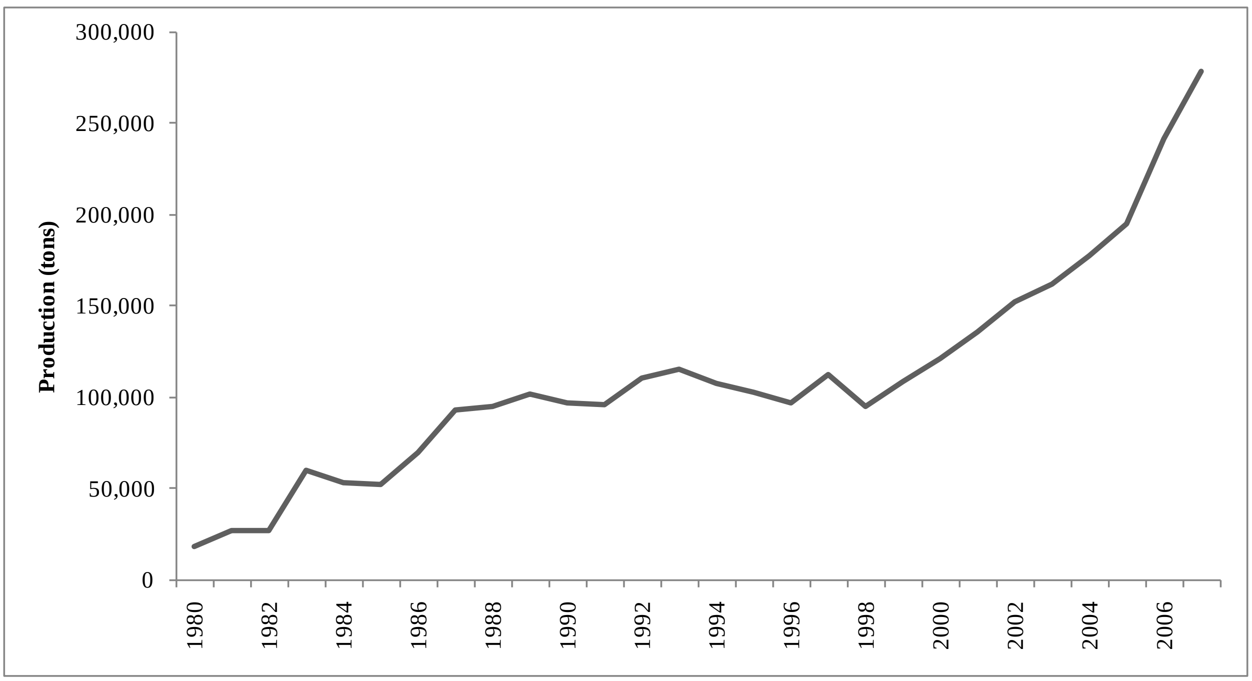
6. IMPACT OF THE AQUATIC CHICKEN IN THE PHILIPPINES

GIFT, GIFT-derived, and other improved tilapia have had a great impact in the Philippines. Improved technologies have worked to further lower tilapia prices, making tilapia more accessible to low-income population groups. The tilapia industry has also provided tilapia farmers with employment opportunities and raised incomes, and has a record of accomplishment of relative environmental and political sustainability. These various impacts will be discussed in more detail below.

Production

In the Philippines, sheer tilapia production numbers have steadily increased over the last three decades, with a notable spike beginning at the turn of the century. In 1980, the Philippines produced 18,540 tons of tilapia; in 1990, this figure had increased to 97,424 tons; by 2007, output was nearly 279,000 tons (Graph 2).

Graph 2. Tilapia Production 1980–2007, Philippines



Source: FAOSTAT 2009

As noted earlier in this paper, the increase in tilapia production in the Philippines has not been as dramatic as in other Asian countries, mostly due to the obstacles encountered with still nascent management and dissemination techniques.[5] Still, while GIFT has boasted higher production and performance numbers in neighboring countries, it can be argued that tilapia holds greater importance in the Philippines, where it is one of two main cultured species in a relatively undiversified fish industry (Table 7).

[5] For example, in Bangladesh, GIFT fish exhibited a 9-25 percent increase in yield as compared to non-GIFT fish, representing a 7-20 percent decrease in the variable cost of tilapia farming. In China and Thailand, the yield difference was 9-33 percent, representing a 7-28 percent decrease in farming costs (Dey 2002).

Table 7. Expenditure share on fresh fish and processed fish, Philippines

Fish Categories	Expenditure Share (%)		
A. Fresh Fish	Total	Rural	Urban
Aquaculture Species	78	74	81
Milkfish	15	10	19
Tilapia	13	11	14
Shrimp	4	2	4
Shells/crabs	2	2	2

Source: Family and Income Expenditure Survey 2000 in Garcia, Dey and Navarez (2005)

The ADB concludes that GIFT and GIFT-derived strains are responsible for most of the increase in tilapia production in the last two decades (Acosta and Gupta 2009). Although the Philippines' Fisheries Statistics Division of the Bureau of Agricultural Statistics does not provide production statistics on different strains of tilapia, a 2004 ADB survey of 136 private and public hatcheries showed that the GIFT strain and the GIFT-derived strain GET EXCEL together comprised 67.6 percent of total tilapia seed produced in the country in 2003 (ADB 2006). This amounted to 623.6 million fry and fingerlings. In terms of tilapia seeds sold, the GIFT and GIFT-derived strains similarly comprised 66.9 percent of total seed sales, an increase of 3.3 percentage points from 2001. Over this two-year period, the market share of GET EXCEL increased from 44.5 to 48.4 percent while GST™ remained stable at an average 18.8 percent (Table 8).

Table 8. Production of different Nile tilapia strains in 2003, Philippines [a]

Strain	Production[b]	Percentage share
GET EXCEL (GIFT-derived)	421.4	45.7
GST™ (GIFT)	201.6[c]	21.9
FAST (nonGIFT)	187	20.3
GMT (nonGIFT)	59.3	6.4
Local (nonGIFT)	35.6	3.8
Israel (nonGIFT)	17.6	1.9

Source: ADB Impact Evaluation Study, survey of Philippine hatcheries (2003)
[a] Survey covered Central, Southern, and Northern Luzon; Bicol; and the provinces of South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos.
[b] In millions of fry and fingerlings.
[c] Hatcheries in Mindanao region used earlier generations of the GIFT strain. Production numbers for the Genomar Supreme Tilapia strain in southern Luzon and Bicol were not disclosed by respondents.

Philippines as Tilapia Exporter

The last two decades have seen an impressive growth in global tilapia production (Vannuccini 2001). From 1990–99, output doubled from 830,000 tons to 1.6 million tons. In 2005, production reached a staggering 2.5 million tons (Josupeit 2007). Production has intensified in response to global demand: many non-producing countries and regions, including the United States, Europe, Central America, and South America, have increased their consumption of tilapia.

While Asia is the main exporter of tilapia, the Philippines lags definitively behind other Asian competitors (Table 9) (El-Sayed 2006). This is because historically, the national marketable size of 143–200 grams has been much smaller than the international marketable size of 400-500 grams for live fish and 700 to 1,000 grams for fish that will be filleted (Dey et al. 2000a; World SeaFood Market 2005). While American consumers demand a large fish that can be filleted, the poor Philippine consumers that comprise the majority of the purchasing bloc for domestic tilapia consumption traditionally preferred a smaller fish (World SeaFood Market 2005). Perhaps due to introduction of GIFT and other macro changes, these preferences have started to shift. In 1995, 58 percent of Philippine households preferred a larger fish (Dey et al. 2000b). The Government of the Philippines is also taking steps to improve the export standing of the country in the tilapia industry. In 2007, BFAR projected that tilapia exports will increase in one year by 150–200 tons, with resources being focused on the top tilapia-producing region in the country (Sun Star 2007). Focus will need to be placed not only on production, but also on packaging and marketing tilapia as fillets, as well as selecting appropriate pricing and distribution mechanisms (ADB 2006).

Table 9. Tilapia imports to the US market (MT) 2001–03

Country	Whole, frozen		Fillet, fresh		Fillet, frozen		Total	
	2001	2003	2001	2003	2001	2003	2001	2003
China	10,870	28,763	191	857	2,529	15,857	13,590	45,477
Taiwan	27,599	19,664	76	286	2,133	2,470	29,809	22,415
Indonesia	39	5.4	--		2,179	3,583	2,218	3,588
Thailand	49	121	2	7	209	940	260	1,068
Hong Kong	--	135	--	--	--	--	--	135
Vietnam	7	41	--	17	53	73	60	132
Burma	--	--	--	--	--	19	--	19
Japan	--	--	--	0.5	--	18	--	18.5
Philippines	51	18	--	--	2	--	53	18

Source: Economic Research Service, USDA.

Tilapia as a Source of Employment and Income

Aquaculture can be more advantageous than other farm activities such as cash crops or livestock production because of relatively inexpensive inputs, low capital requirements, and low labor requirements (El-Sayed 2006). Despite the small amount of labor required for tilapia farming, it is estimated that 280,000 people in the Philippines benefit directly or indirectly from employment in the tilapia industry (CGIAR 2006). The tilapia industry provides employment in excavation of ponds, cage and net making, fish feeding and harvesting, sorting and grading, marketing, transport, among others. The hatchery industry employs an average of 3.4 persons per hectare, or 3,900 additional people. Two thirds of the nation's 604 hatcheries are dedicated to producing GIFT and GIFT-derived seed (ADB 2006). Although tilapia farming is a male dominated occupation, females comprise 11 percent of improved tilapia growout farmers and hatchery operators. That number jumps to 33 percent among GIFT users involved in hatchery operations (Table 10) (Sevilleja 2006). Thus, it can be said that improved tilapia operations are *relatively* inclusive of women.

Table 10. Gender of improved tilapia growout and hatchery farmers

Gender	Growout (% of farmers)				Hatchery (% of farmers)			
	GIFT	EXCEL	FaST	All strains	GIFT	EXCEL	FaST	All strains
Male	88	82	90	88.5	67	94	71	89
Female	12	18	10	11.5	33	6	29	11

Source: Sevilleja (2006)

As previously mentioned, most tilapia farmers rely on semi-intensive systems that yield substantial profits (Dey and Gupta 2000). Average net returns from improved tilapia farming have been shown to be particularly high. Ninety-seven percent of these farmers culture improved tilapia fish as a cash crop and most farmers sell more than 30 percent of their harvested product (Eknath and Acosta 1998). The major costs associated with tilapia farming are the cost of feed and the cost of fry or fingerling.

Tilapia hatchery farming for the Philippines and Thailand yields average net returns of $5,074/ha/year; $1,867–4,241/ha/four-month crop cycle for growout operations, not including on-farm household fish consumption; and $390/cage/cycle for growout cages. Cage farming in central Luzon and Taal Lake has potential yields of $3,120 annually for a farmer (Acosta and Gupta 2009).[6]

Growing improved strains of tilapia in the Philippines also represents significant reductions in production costs for farmers. Depending on the production environment, improved strains are 32–35 percent cheaper to produce than non-improved strains (Table 11).

Table 11. Yield and variable costs of tilapia pond farming using GIFT and non-GIFT strains, Philippines

Item	Cage	Pond
GIFT		
Yield (kg/unit area)	236	1,361
Variable cost	168	1,385
Variable cost of fish/kg	0.71	1.02
Non-GIFT		
Yield (kg/unit area)	153	912
Variable cost	168	1,375
Variable cost of fish/kg	1.1	1.51
Percentage difference		
Yield	54.2	49.2
Variable cost	0	0.7
Variable cost of fish/kg	-35.5	-32.5

Source: Dey (2002), as presented by Gupta and Acosta (2004)

Distribution of Benefits to Producers

As has been noted, tilapia dissemination strategies have been described as passive because they were not able to reach as many small-scale farmers as had been hoped (Mair et al. 2002). There is truth to this claim. A study completed by ICLARM indicated that the land area of hatcheries involved in improved tilapia is small, with 80 percent having an area less than 0.25 hectares. Land area for growout farmers, those engaged in the marketing stage of fish culture, was on average 1.7 hectares (Eknath and Acosta 1998). However, Filipino fish farmers have the largest landholdings among pond operators throughout Asia (Dey et al. 2000b). GIFT users in hatcheries there own an average area of land totaling 10.53 hectares, even bigger than the average land owned by a typical Filipino fish farmer (Acosta et al. 2006).

The demographics for tilapia users imply that farmers with a high level of expertise are better able to access improved tilapia technologies (Sevilleja 2006). Additionally, although the majority of users of improved tilapia are small landowners, those with access to capital through their own private sources (57-92 percent of tilapia investment was typically sourced from personal funds) are better equipped to receive the benefits of improved tilapia through private-sector collaboration (i.e., GIFT/GST), suggesting that the current dissemination mechanism fails to reach small and poor tilapia farmers (Sevilleja et al. 2006).

The obstacles facing small-scale fish farmers are indeed numerous. Many small-scale fishers engaged in aquaculture face high input costs as well as poor bargaining power amidst exploitation from

[6] For four cages and two harvestings.

traders and middle agents (Ahmed and Lorica 2002). This problem is compounded by hatchery market channels; nearly 75 percent of hatcheries sell all or the majority of their fingerlings to traders, instead of directly to growers (Eknath and Acosta 1998). Legal documentation requirements associated with the GIFT hatchery accreditation process tend to limit interested hatchery operators to those with a high level of education, business expertise, and access to capital (Rodriguez 2006).

At the same time, the criticisms of the poverty focus of improved tilapia activities should be slightly tempered. A study of the poverty levels of hatchery and growout farmers showed that fishpond owners represented 10-45 percent of all village households in the middle-income strata and 23-55 percent of households in the rich income strata. Additionally, the majority of growers did not have access to formal credit. The authors conclude that there is no evidence that it is the poorer or richer members of communities that enter into aquaculture (Eknath and Acosta 1998). Additionally, the monoculture technology that is prevalent in the Philippines has been found suitable for the poor, especially in the context of herbivorus species, as this method does not require high capital (Dey et al. 2005). The GIFT strain is regarded as a scale neutral technology when considering feed and fertilizer use. This means that smallholder farmers who use fewer inputs and big farmers who use more will get proportionate benefits (Acosta and Gupta 2009). Although among improved strain users, tilapia farming represents a secondary source of income (with the exception of FaST users, who do consider farming to be a primary source of income), its contribution to their total income is considerable (Table 1.11) (Acosta et al. 2006). As such, despite challenges, only 3-7 percent of pond operators planned to discontinue tilapia farming, with 20-46 percent anticipating that they will actually expand their operation (Dey et al. 2000b).

Table 12. Tilapia farming as source of income among improved tilapia users

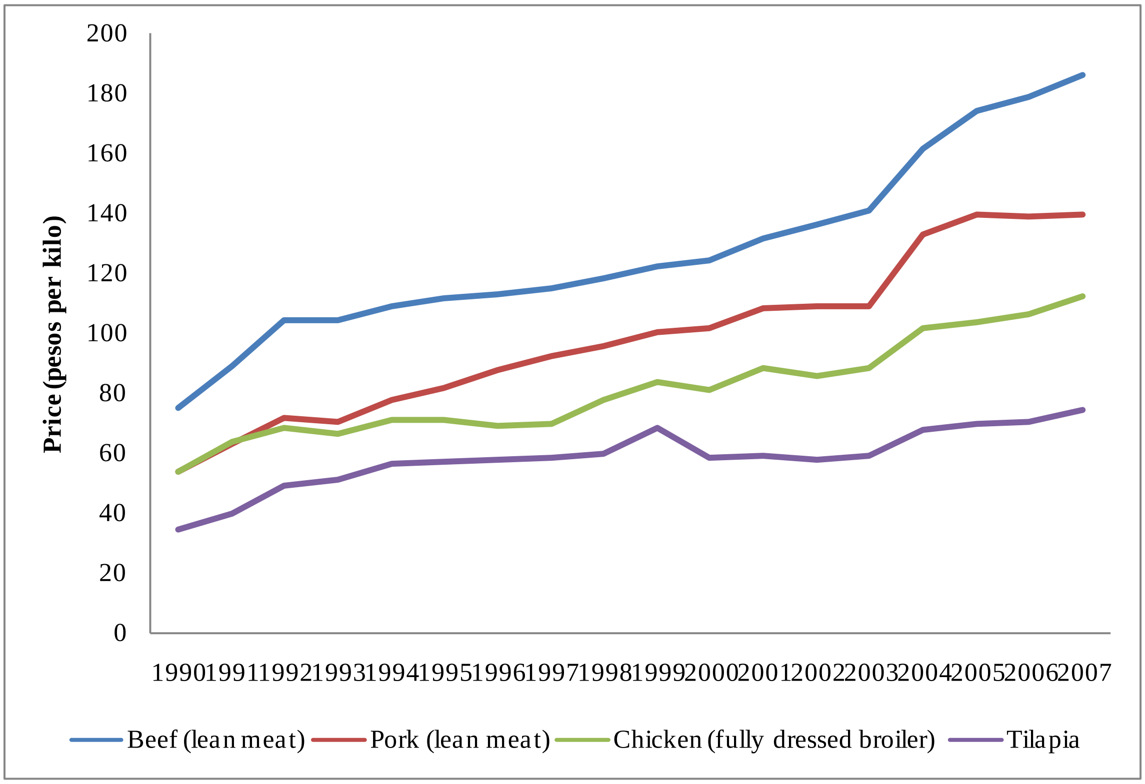
Strain	Tilapia farming as primary source of income (%)	% of income from tilapia farming
Growout		
GIFT/GST	24	39
GET EXCEL	20	38
GMT	16	35
FaST	60	74
Hatchery		
GIFT/GST	83	64
GET EXCEL	55	56
YY	25	34
FaST	47	61

Source: Sevilleja 2006

Tilapia as a Low-Priced, Nutritional Fish

As demonstrated, the genetic strides made in tilapia have helped increase national production, working to keep tilapia prices low for consumers. As a source of protein, tilapia is generally more affordable than pork, beef, or chicken, even when compared to other freshwater fish. For example, the average price of tilapia was 35 Philippine pesos per kg in 1990 and 74 pesos in 2007, representing an increase of 111 percent. In contrast, during this same period, beef jumped 148 percent and pork 157 percent (Graph 3). Dey (2000) concluded that adopting improved tilapia species would reduce tilapia prices by 5–16 percent in various Asian countries, including Bangladesh, the Philippines, Thailand, China, and Vietnam.

Graph 3. Retail prices of tilapia, pork, beef, and chicken in the Philippines, 1990–2007

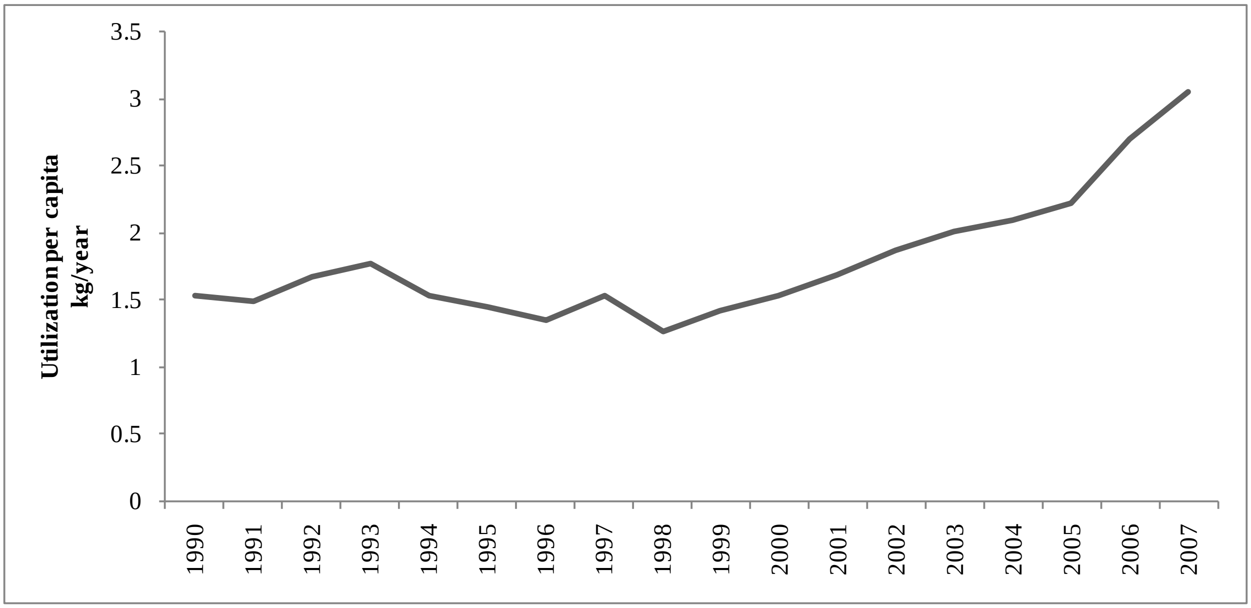


Source: Philippines' Bureau of Agricultural Statistics

Tilapia is also a significant source of protein. While eggs, milk, rice, and wheat have anywhere from 3.5 to 12 percent protein, fish contain about 16–20 percent protein, as well as a variety of essential minerals, vitamins, and amino acids. In Asia, fish protein comprises an average 31 percent of total animal protein supply, with this figure jumping to as high as 51 percent in Bangladesh, 58 percent in Indonesia, and 75 percent in Cambodia (Acosta and Gupta 2009). For the poorest of the poor, fish is often the only source of animal protein (Kumar 1992). GIFT fish have been shown to have 17 to 21 percent protein content, representing a 4.7 to 5.5 percent increase in whole-body protein content over red hybrid tilapia strains, showing that protein efficiency and utilization is influenced by tilapia genotype (Ponzoni et al. 2008, Ng and Hanim 2007).

A combination of high nutritional value and high consumption is good news for food security. In 1997–2001, Filipino national consumption of fish and fishery products averaged 2.3 million metric tons, increasing 2.2 percent annually (Garia, Dey, and Narvaez 2005). As multiple macro and microlevel confounding factors affect consumption, the causality between improved tilapia and increased consumption has not yet been established. However, consumption of tilapia in particular has increased recently. Prior to the development and introduction of genetically improved strains, average per capita consumption of tilapia in the Philippines was 0.66 kg per year. By 2007, this amount had increased by 362 percent to 3.05 kg (Graph 4) (PBAS 2009).

Graph 4. Tilapia utilization per capita (kg/year) in the Philippines, 1990–2007



Source: Philippines' Bureau of Agricultural Statistics

No estimates are readily available for the number of Filipinos who have benefited from these low prices. Falck-Zepeda and Horna (2009) conducted an ex-post evaluation of GIFT and GIFT-derived tilapia using an economic surplus approach. This method involved converting quantities of tilapia to calories, and approximating consumed quantities from acquired quantities to arrive at the additional amount of protein and energy available to consumers. Assuming that improved tilapia can contribute to 50 percent of daily intake, they estimated that an additional 18–21 million people are able to fulfill their daily protein requirements while another 1.3–1.6 million people are able to fulfill their daily caloric requirements.

The quantity and quality of fish consumption varies widely in the Philippines according to income strata. In 2000, the monetary value of per capita fish consumption among wealthy consumers was 3.4 times that of the poorest consumers (Garcia, Dey, and Navarez 2005).[7] Poor consumers tend to spend their income on cheaper fish, including processed fish. As their incomes increase, these consumers tend to spend a smaller proportion of their budget on fish, and a larger proportion on meat. This means that poor households rely more on fish as their primary source of animal protein, although fish remains a necessary group in all income groups (Garcia, Dey, and Navarez 2005). Figures from 1995 show rural tilapia farmers consuming an average of 39.5 kilograms of fish every year, with rural non-producers consuming 15.9 kg and urban non-producers, 5.8 kg (Dey et al. 2000b).

[7] Wealthy consumers are those with an average income of 91,097 Philippine pesos, while the poorest consumers have an average income of 7,244 Philippine pesos. Source: Family and Income Expenditure Survey as analyzed by Garcia, Dey, and Navarez (2005).

Table 13. Tilapia consumption in non-producer households by expenditure class

Expenditure Quantile	Share of tilapia in total fish consumption (%)
1	25.52
2	25.18
3	35.29
4	44.95
5	53.33

Source: Dey et al. (2000)

Tilapia follows these income-related consumption patterns, exhibiting a particularly high consumption share among the poorest segment of the national population. In 2000, for example, the average consumption share of tilapia for the poorest quintile was 0.084, only outranked in the freshwater fish category by roundscad, which had a share of 0.158 (Garcia, Dey, and Navarez 2005).

Indeed, tilapia is very popular among the poor in the Philippines. Nationally, it has a demand elasticity of 1.24 for the lowest-income populations and 0.99 for the high-income groups. Following this pattern, a 10 percent drop in tilapia prices would increase the lower income group's tilapia consumption by 12.4 percent (Garcia, Dey, and Navarez 2000). Household survey results confirm the popularity of tilapia among this segment of population: in one, 85–100 percent of respondents reported consuming tilapia 1-3 times a week; in another, 65 percent of respondents preferred tilapia to other fish species (Dey et al. 2000b; Mair et al. 2002).

Returns

A study conducted by Ponzoni et al. (2007) found that the national economic benefit derived from GIFT's genetic improvement activities was extremely favorable. Even with relatively simple operational systems, such as ponds operating with moderate efficiency, the economic benefit of such activities was valued at over $4 million, while the benefit-cost ratio was 8.5. Upgrading the reproductive efficiency of these contexts by introducing available and inexpensive technologies like *hapas*, artificial incubation, and good management, raised these values to $32 million and $60 million, respectively.

The internal rate of return of the development and dissemination of GIFT was estimated to have been more than 70 percent from 1988–2010 (ADB 2006). As a comparison, for tilapia in the Philippines inclusive of both GIFT and non-GIFT strains, the rate of return for monoculture of tilapia in cages was 20 percent while that of monoculture in ponds was 30 percent in 1999 (Dey et al. 2005).

7. SUSTAINABILITY OF TILAPIA FARMING

Environmental

In developing countries such as the Philippines, the use of antibiotics or chemicals in aquaculture production is generally less intense than in other parts of the world (Charo-Karisa 2008). Even so, with the recent trend toward intensification of tilapia farming, the tendency to turn to such artificial farm inputs as prepared feed, hormones, and fuels, will only grow, increasing with it possible ecological and health impacts (El-Sayed 2006).

Many fish farming operations, especially those intended for export markets, include carnivorous species with high protein needs. An individual carnivorous fish may consume four to five wild fish to meet its dietary requirements, thus depleting stocks of natural fish populations (Ahmed and Lorica 2002). The expansion of this type of aquaculture has placed pressure on capture fisheries through increased demand for captured fish for use as feed (Dey and Kanagaratnam 2008). Although Nile tilapia is naturally herbivorous, mainly consuming phytoplankton among other natural food organisms, selective breeding programs such as GIFT are often undertaken for tilapia in ponds that receive high protein supplementary feed. Aside from being costly, comprising up to 60 percent of fish production costs, these supplementary feeds are not environmentally ideal as they may lead to further depletion of indigenous stocks (Charo-Karisa 2008)

Indeed, depletion of local fish may be the central issue with GIFT tilapia (Charo-Karisa 2008). As has been mentioned previously, the introduction of Mozambique tilapia and Nile Tilapia in the 1950 and 1970s garnered tilapia the reputation of being prolific breeders. The impact of these introductions on biodiversity, compounded with overfishing, pollution, siltation, and water diversion, makes it difficult to assess the impact of Nile tilapia in Philippine lakes (ADB 2006).

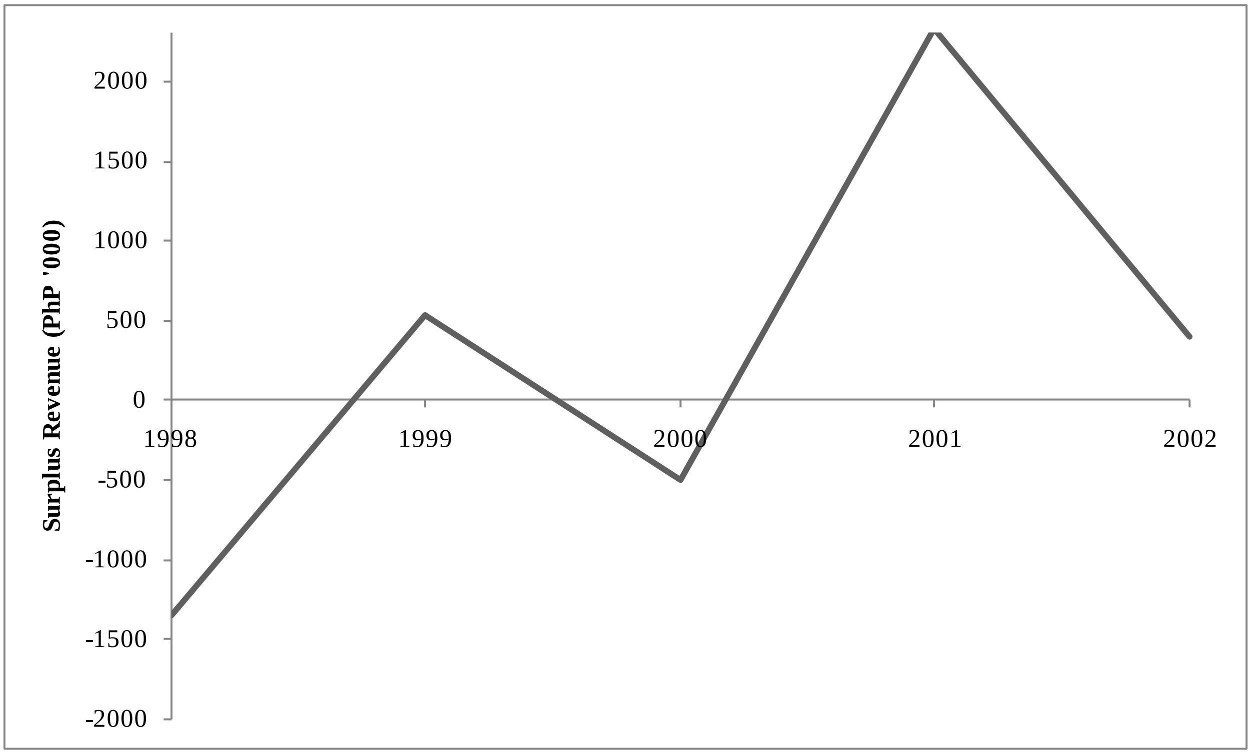
At the same time, it should be noted that the precautions taken by WorldFish toward invasive species issues under the GIFT program were particularly extensive. For example, the founder tilapia stocks from Africa were kept under strict quarantine for 3-7 months. INGA protocols for the responsible movement of fish germplasm were also continuously followed (ADB 2006). A 521-farmer survey conducted in countries participating in the GIFT program found that 16 percent of respondents saw a displacement or reduction in catch of existing species. However, an assessment team that was brought out to confirm these claims did not find any displacement in natural waterways other than lakes and reservoirs (CGIAR 2006). Additionally, an international workshop on possible environmental impacts of GIFT strains concluded, "responsible development and dissemination of GIFT would be unlikely to cause serious environmental damage (CGIAR 2006)."

El-Sayed (2006) notes that the predicted future shortage in fresh water will necessitate innovations in tilapia culture. Tilapia will increasingly need to be produced in closed-recirculation systems, alongside improvements in aeration, filtration, and feeding techniques, waste settlement and removal, and reuse of water.

Financial

The institutions responsible for genetic research in the Philippines are funded through grants, government monies, seedstock sales, and partnerships with private-sector actors. Since 1998, GFII operating revenues have been sourced from fingerling sales, fees associated with issuing hatchery licenses, and grant service income (Rodriguez 2006). A sizeable amount of this revenue, 15 million Philippine pesos, has gone toward maintaining and breeding of its own independent nucleus. GFII's financial health, as measured by the relationship between operating revenue (generated from fingerling sales and licensing fees) and R&D expenditures (comprising personnel, supplies, services, travel, and depreciation of fish stocks), has been slightly unpredictable over the long term (Graph 5).

Graph 5. GIFT Foundation international operating revenues and expenses[a]



Source: Rodriguez (2006) as presented in Acosta et al. (2006)
[a] In million Philippine pesos

In terms of external funding, tilapia genetics research has received more than $7 million since 1979 from such international organizations and aid agencies as the ADB, Department for International Development (DFID), UNDP, and ICLARM, among others. National support has totaled more than $1.2 million and has been sourced from the Commission on Higher Education, Central Luzon State University, Department of Agriculture, and the Philippine Council for Aquatic Marine Research and Development, among others (ADB 2006). It took approximately 10 years of investment and technical assistance to see GIFT through the entire agricultural value chain: from germplasm collection, selective breeding, on-farm trials, establishment of national breeding programs, and distribution (ADB 2006). This makes the case that sustained investment can pay big dividends in the long term.

Political

In the past, national fisheries services have not always received the necessary resources and management oversight to allow the improved tilapia industry to thrive (Sevilleja 2007). The 1987 Philippine Constitution, however, explicitly recognized the role of the state in the management of aquatic resources, stating that the state will support appropriate technologies and research and provide financial backing for production and marketing of marine resources (Sevilleja 2007). Following this development, the Government of the Philippines has emerged as a central player in improved tilapia breeding and dissemination, its role backed by both national legislation and infrastructure that support fish genetics research and aquaculture. The Agriculture and Fisheries Modernization Act (AFMA) of 1997, for example, promoted the state's role in science and technology, while the Philippines Fisheries Code of 1998 called for the creation of a National Fisheries Research and Development Institute for elevating the Philippines as one of the top five fish producers in the world (Abella 2006).

Under AFMA, the Department of Public Works and Highways currently works alongside the Department of Agriculture to provide the necessary infrastructure vital to the fisheries sector. This includes building and maintaining fish and seaports, storage facilities, roads connecting farms to markets, water supply systems, and communication, research, and technology infrastructure (Sevilleja 2007). As part of an overall effort toward building institutional capacity for management, training, and extension services, BFAR has been brought under the Department of Agriculture, one of whose major functions is to prepare and implement a Comprehensive National Fisheries Development Plan (Sevilleja 2007).

Local government administrative units also now offer basic fisheries extension services and have created local environment and natural resources councils comprising government agencies, civil society organizations, and non-governmental agencies. These councils create an environment conducive to a multistakeholder policymaking process (Sevilleja 2007). As has been shown earlier in this paper, the remaining area of weakness lies within the harmonization of public and private sector roles in seed supply; policies toward this end have not yet formally been enacted (ADB 2006).

In 2003, Philippines President Gloria Arroyo declared that tilapia would soon replace the local fish, *galunggong*, as the national staple fish (CGIAR 2006). A year later, the country hosted the Sixth International Symposium on Tilapia and Aquaculture in Manila. These various developments suggest a sound political environment for the continuation of improved tilapia activities in the future.

8. LESSONS LEARNED

Changes in Tilapia Hatchery and Farming Practices

Tilapia seed producers now have wider access to high-quality tilapia broodstock, and are able to manage them more carefully by replacing spawners, or those fish that produce young, every 18–24 months. The availability of a wide array of strains, including GIFT/GST™ , GET EXCEL, YY, and FaST, makes seed producers more willing to try new technologies. For example, a microlevel analysis of hatchery operators in the Philippines showed that 75 percent of hatchery operators were aware of GIFT fish and were willing to take on new technologies, as well as use better tilapia strains when they are available at reasonable prices (Bimbao et al. 2000). Farmers too have been able to more intensively managed ponds, harvesting fish after 3–4 months instead of the pre-GIFT 6–7 month production cycle (ADB 2006).

Developing-Developing Technology Transfer

The GIFT project represented the first ever systematic collection and transfer of Nile tilapia germplasm from Africa to Southeast Asia. While this is a positive development because it runs counter to the common characterization of technology and knowledge transfers originating exclusively in the developed world, Africa has unfortunately not received benefits from the transaction thus far. This is mainly due to the WorldFish Center's past policy of not introducing GIFT fish to countries where it is indigenous for fear of possibly contaminating wild germplasm (Gupta and Acosta 2004). For many years, this obstacle was minimally overcome by applying the GIFT methodology towards the improvement of other indigenous tilapias in such countries as Cote d'Ivoire, Egypt, Ghana, and Malawi (WorldFish Center 2003). Recently, WorldFish reversed its decision and made GIFT fish available to any African government that could demonstrate that it had a well-defined maintenance and dissemination strategy for the fish, as well as a plan on how to manage environmental and biodiversity risks (WorldFish Center 2007). Any willing government still has to abide by the Convention on Biological Diversity, which seeks to protect ecosystems from alien species (Acosta and Gupta 2009).

It has been estimated that introducing GIFT to Africa may improve growth of the current stock by 64 percent (Ponzoni et al. 2008).

Extension Matters

While traditional tilapia farming does not currently reach the poorest of the poor in the Philippines on a large-scale basis, genetic-based technologies may be better equipped to benefit these types of populations, but only when coupled with complementary services. Strengthening the presence and outreach of extension officers would not only enable the diffusion and adoption of a particular technology, but would also serve as a feedback mechanism to scientists, in turn enabling them to further improve and refine technologies. Ultimately, a stronger extension system translates into technologies that are relevant to their end-users.

Gene Banking, Breeding Technology, and Institutional Capacity

Aquaculture has been framed as one of the most viable ways of increasing fish production, and food production, over the next century. The GIFT program has proved that much benefit is to be gained from applying genetics to aquaculture, especially selective breeding, which is a particularly cost-effective way of achieving genetic improvement.

Prior to GIFT, the Philippines did not have systematic banking for farmed fish genetic resources. In fact, fish gene banks are relatively rare, especially in tropical developing countries. The GIFT project introduced technology and training for gene banking and now maintains a tilapia gene bank that is of international importance (ADB 2006). GET EXCEL has been the premier product coming out of this gene bank. If it were not for the ready availability of FaST and GIFT germplasm, researchers would have been forced to re introduce wild tilapia strains from Africa once again, thus stalling the creation and dissemination of GET EXCEL.

The GIFT selective breeding technology can also now be applied for the genetic improvement of other species. Being that cultured fish stocks have been shown to be inferior to wild populations in the past, the prospects for future cultured fish production are hopeful (Pullin and Capili 1988). GIFT technologies and methodologies are currently being applied to carp, the world's most popular farmed fish, in Bangladesh, Thailand, India, Vietnam, and China (Acosta and Gupta 2009). Some experiments have shown genetic improvements of up to 50 percent (Acosta and Gupta 2009).

Multi-Level, Multi- Sectoral Cooperation

The success of GIFT was buoyed by a vast and multilevel network of international and national research institutes, governments, private actors, and donors. In its role as host country, the Philippines and its national fisheries bureaus and centers made many important contributions to the evolution of the project, including acting as the testing ground for the initial rounds of research and dissemination of improved tilapia. INGA, an international network of multisectoral actors, helped in coordinating global linkages, transferring tilapia germplasm, technical expertise, and lessons learned for institutional capacity-building across borders. Scientists from developed and developing countries alike contributed expertise and training, while private hatcheries throughout the Asia region have been integral to the wide dissemination of improved tilapia strains. International donors provided sustained investment, seeing the project to the end of the agricultural value chain. Finally, the WorldFish Center successfully coordinated all of these activities, in the process becoming renowned as the world leader in tilapia breeding research.

9. CONCLUDING REMARKS

By the year 2050, the world's population is projected to stand at over 9 billion. Faced with a booming population, a stagnant food supply, and increased pressures on natural resources, the developing world will have to take some drastic measures. In order to even minimally feed their citizens, Africa will need to increase food production by 300 percent, Latin America by 80 percent, and Asia by 70 percent (Gupta and Acosta 2004).

Genetically improved tilapia may well be able to solve an important part of this food security puzzle. Over the last two decades, it has positioned itself as a low-cost, high yielding, and profitable fish. The tilapia industry has offered direct, measureable benefits by way of nutrition, employment, and income generation, as well as indirect benefits that include increased availability of fish in local rural and urban markets at a lower price that meet booming consumer demands.

The resounding success story has been buoyed by several encouraging factors. First, a strong commitment on the part of the Government of the Philippines to create a favorable policy environment, set up infrastructure, and lead the way in research and development despite past setbacks was key in producing a series of exciting fish strains. Second, strong public-private partnerships in the dissemination phase enabled the public's access to improved strains, and set the stage for regulation of participating hatcheries. Third, regional networks coordinated technology transfers to other countries, as well as initiated such projects as DEGITA for the purposes of monitoring and evaluation. Finally, a strong *initial* mandate to apply the lessons learned in tilapia to the larger aquaculture picture is now coming to fruition.

What remains to be seen is whether improved tilapia can overcome the challenges associated with poor management, dissemination, and limited natural resources, especially fresh water. For all the successes in tropical finfish improvement in the Asian region, genetically improved fish stocks still account for less than 1 percent of global aquaculture production (Pullin and Capili 1988). Aquaculture only stands to gain from genetic work. While the improvements that are achieved through genetic selection may seem limited in a small population of fish, the cumulative gains that occur in millions of fish as that gain is disseminated to hatcheries and farmers can be a powerful tool in the sector (Ponzoni 2007). If the successes highlighted in this case study can be further scaled up, as has thus far been done in the Asian region, the food security of future generations can be significantly improved.

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