ADB

An Impact Evaluation of the Development of Genetically Improved Farmed Tilapia

AND THEIR DISSEMINATION IN SELECTED COUNTRIES

OPERATIONS EVALUATION DEPARTMENT
Asian Development Bank

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Foreword

Aquaculture, or fish farming, is the fastest growing animal food-producing sector in the world. In Southeast Asia, tilapia farming is a major factor in this phenomenon and has developed mainly around one species, Nile tilapia. Tilapia farming in Asia began to prosper in the 1970s and was accompanied by region-wide advances in hatchery technology and pond husbandry. Unlike in land animal farming, where selective breeding is centuries old, the genetic aspects of most fish farming, including tilapia farming, were neglected until the mid-1980s. By that time, the consequences of this lack of attention to genetics was beginning to show in stagnating tilapia yields. In response, the International Center for Living Aquatic Resources Management (ICLARM; now the WorldFish Center) and the Institute for Aquaculture Research, Norway (AKVAFORSK) and their aquaculture research partners in the Philippines, proposed an international research and development effort on the genetic improvement of farmed tilapia in order to increase productivity, with all necessary environmental safeguards.

The Asian Development Bank (ADB) contributed to this effort over the decade 1988–1997 through two regional technical assistance projects, supporting the research and then dissemination and evaluation of the genetically improved farmed tilapia (GIFT). Other funding support came from ICLARM, the United Nations Development Programme, and national research partners in Bangladesh, People's Republic of China, Philippines, Thailand, and Viet Nam.

The work was notable for the international collaboration and networking that it fostered among institutions in the participating countries, AKVAFORSK, and ICLARM. This resulted in increased capacity and improved infrastructure for tilapia genetics at the national level. The networking in aquaculture genetics research that began with this work has grown substantially. It now includes linkages and collaboration among national research scientists in the Asia and Pacific region and Africa (the home of tilapia) as well as with advanced scientific institutions in Asia, Australia, Europe, and North America, for research and dissemination of breeding material, often through public-private partnerships.

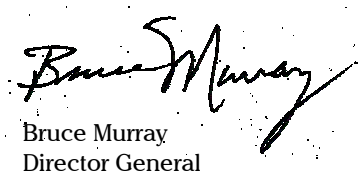
The development of GIFT has shown that selective breeding is a feasible and cost-effective approach to the genetic improvement of tropical farmed fish. GIFT were developed without the need for any application of controversial biotechnology or genetic modification. GIFT have become major contributors to national tilapia breeding programs, and to production of farmed tilapia in the Asia and Pacific region. Research methods and protocols proven during the development, dissemination, and evaluation of GIFT are now being applied in Asia and the Pacific and other developing regions to other widely farmed fish, notably Asian carps.

This impact evaluation study probes the catalytic effects of the initiative; illustrates its various outcomes and impacts; distils pertinent lessons, issues, and opportunities; and provides recommendations for further research and development and dissemination for greater impact on poverty reduction.

Four country case studies—in Bangladesh, the Philippines, Thailand, and Viet Nam—form the basis of the study's findings. Overall, it is clear that tilapia farming now contributes very significantly to food security, incomes, and employment. For example, in the Philippines, farmed tilapia is now recognized as the most important food fish for poor consumers. In 2003, President Gloria Macapagal Arroyo of the Philippines stated that the round scad or *galunggong* would soon be replaced by tilapia as the food of the masses. The contribution of tilapia to human nutrition, in the context of the Millennium Development Goal to reduce hunger and poverty, indicates that further support for research on genetic improvement of tilapia and their dissemination is warranted.

The report was produced by a team under the supervision of Graham Walter of the Operations Evaluation Department. Njoman George Bestari, senior evaluation specialist (team leader), was responsible for preparation of the report. Maria Rosa Ortega, evaluation officer, supported the study with research assistance. The study received substantive inputs from Brenda Katon (research associate, consultant), Roger Pullin (aquatic resources management consultant), and researchers in Bangladesh (M.G. Hussain), Philippines (Tereso Abella and Ruben Sevilleja), Thailand (Nuanmanee Pongthana), and Viet Nam (Pham Anh Tuan), and from Uttam Deb and Madan Dey of the WorldFish Center. Stephen Banta and Jay Maclean edited the report, Caren Joy S. Mongcopa (senior operations evaluation assistant) did the formatting and layout, and Ramiro Cabrera designed the book cover.

We hope that the findings of this impact evaluation study will prove useful to countries seeking to improve the farming not only of tilapia but also of other farmed fish for increased productivity and relevance to poverty reduction.



Bruce Murray
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Abbreviations

AAGRDI	Aquatic Animal Genetics Research and Development Institute
ADB	Asian Development Bank
AIT	Asian Institute of Technology, Thailand
AKVAFORSK	Institute for Aquaculture Research, Norway
BFAR	Bureau of Fisheries and Aquatic Resources, Philippines
BFRI	Bangladesh Fisheries Research Institute
CLSU	Central Luzon State University, Philippines
DEGITA	Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia
DOF	Department of Fisheries, Thailand
FAC	Freshwater Aquaculture Center of CLSU, Philippines
GFII	Genetic Improvement of Farmed Tilapia Foundation International Incorporated
GIFT	genetically improved farmed tilapia
GMT	genetically male tilapia
ICLARM	International Center for Living Aquatic Resources Management
IDRC	International Development Research Centre, Canada
IES	impact evaluation study
INGA	International Network on Genetics in Aquaculture
Lao PDR	Lao People's Democratic Republic
MTADP	Medium Term Agricultural Development Program
NAGRI	National Aquaculture Genetics Research Institute, Thailand
NESDP	National Economic and Social Development Plan, Thailand
NFFTC	National Freshwater Fisheries Technology Center of BFAR, Philippines
NIFI	National Inland Fisheries Institute, Thailand
NORAD	Norwegian Agency for Development Cooperation
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PRC	People's Republic of China
R&D	research and development
RIA	Research Institute for Aquaculture, Viet Nam
SRT	sex-reversed tilapia
TA	technical assistance
UK	United Kingdom
US	United States
UNDP	United Nations Development Programme

WEIGHTS AND MEASURES

g	gram
ha	hectare
kg	kilogram
m	meter
t	metric ton

NOTE

In this report, "$" refers to US dollars.

Glossary

Base population	An initial, randomly mating population of fish that is used as the basis for subsequent selective breeding.
Biosafety	The provision of safeguards (for example, quarantine procedures) for the health and survival of biodiversity, both wild and farmed. This term is used here in the broad sense, encompassing all such safeguards and biodiversity, as opposed to its use in the narrow sense, referring only to safeguards with respect to genetically modified organisms, especially plants.
Breed	A distinct group of a farmed or other domesticated species, descended from common ancestors and having visibly similar characteristics.
Breeding history	The genetic lineage of an individual or population.
Breeding program	The management of broodstock and individual breeders over successive generations so as to improve desirable traits that are largely or exclusively genetically determined, i.e., heritable.
Broodstock	A captive population of fish, kept for breeding purposes or for mass production of fish seed for farming or release.
Crossbreeding	see Hybridization.
Cryopreserved sperm	Fish spermatozoa, stored in liquid nitrogen; the same technology that is widely used for semen storage in livestock breeding.
Detritus	Complex food resource on the bottom of fishponds and other water bodies, consisting of microscopic living organisms (chiefly bacteria, fungi, microalgae, protozoans, small worms, crustaceans, and other invertebrates) and the

	matrix of organic and inorganic material in which they live.
Dressing weight	The weight of the marketable parts of a harvested fish after the parts unwanted by humans (usually the viscera) have been removed.
Fingerling	Young fish about the length of a human finger; see Fish seed.
Fish seed	The early life history stages of fish (eggs, larvae, fry, and fingerlings) that are raised in hatcheries or collected from the wild for use by fish farmers.
Founder population or Founder stock	The sexually capable individuals that comprise a new population established for breeding purposes.
Fry	Young fish of very small size, usually only a few centimeters in length; see Fish seed.
Gene bank	A facility established for the ex situ conservation and use (in breeding programs, production, and research) of genetic material, e.g., for fish, collections of broodstock and/or cryopreserved sperm of different strains.
Genetic characterization	The identification and taxonomy of individuals and populations using morphological, metric, and biochemical characteristics.
Genetic material	see Germplasm.
Genetic modification	The artificial transfer of specific genes from one taxon to another. New organisms thereby produced are commonly called genetically modified organisms (GMOs). This area of biotechnology and its products are not involved in the work evaluated here.
Genetic variability	The total amount of genetic variation in a population, conferring scope for future adaptations through natural selection and for improvement of some commercial traits by selective breeding.

Genetically male tilapia (GMT)	An individual male tilapia or an entirely male population of tilapia that has been bred so as to have only male sex chromosome combinations (XX or YY).
Germplasm	A general term for genetic material, usually in the form of whole living organisms or as gametes (eggs and/or sperm) or embryos, used for breeding purposes, conservation, or research.
Heritable	Refers to a trait or character that is inherited by progeny from their parents.
Hybrid vigor	Substantial improvement in hybrid progeny of one or more performance traits compared with measurements of the same in the parents.
Hybridization	The mating of parents of different strains, breeds, species or, in rare cases, higher taxa to produce crossbred individuals or populations, which are known as hybrids or crossbreeds; also called crossbreeding.
Inbreeding	The mating of related individuals.
Local adaptation	Increased fitness of a population that has adapted to a specific local environment by natural selection.
Phytoplankton	Microscopic plant life, often single-celled organisms, in the water column of fishponds and other water bodies. Here, the term includes the so-called blue-green algae or cyanobacteria.
Polyculture	The farming of more than one species of fish in the same pond, cage, or other container.
Provenance	The authenticated origin of an acquired object; here applied to fish, acquired for breeding or production purposes.
Quantitative genetics	The subdiscipline of genetics that deals with quantification of traits in breeding.
Selection	see Selective breeding.

Selective breeding	Choosing the best performing individuals or families to become the parents of the next generation; more commonly called selection in genetics literature.
Sex reversal	Artificial manipulation of sex (of tilapia), usually by feeding populations of mixed sex early fry for a brief period with feed containing an androgenic hormone. This changes females into males and enables the farming of all-male populations. There are no risks to consumers.
Strain	Distinct variety of a farmed or other domesticated species.
Taxon (pl. taxa)	A group at a given rank or level in a classification scheme, for example, family, species, and subspecies.
Trait	A detectable (and usually desirable) attribute of a farmed or other domesticated organism, e.g., fast growth, body shape, quiet behavior.

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EXECUTIVE SUMMARY

Aquaculture has been growing more rapidly than any other animal food-producing sector in the world. Most of the world's recent increases in per capita food fish supply have been obtained from aquaculture. Worldwide, more than 1 billion people rely on fish as an important source of animal protein, healthy lipids, and essential micronutrients. Unlike crops and livestock, most farmed fish have very short histories of domestication and genetic improvement, and many still closely resemble their wild relatives. The world's first International Symposium on Genetics in Aquaculture was convened only in 1982. Up to the mid-1980s, most aquaculture research and development (R&D) was targeted at seed production technology and improved fish husbandry rather than at genetic improvement.

Nile tilapia farming in Southeast Asia began to prosper in the 1970s, particularly in the Philippines and Thailand. There were contemporary, regionwide advances in tilapia hatchery technology and in pond and cage husbandry. These advances all contributed to boosting production of farmed tilapia and masked this lack of attention to their genetics in the 1970s and 1980s. During the 1980s, some consequences of the lack of attention to tilapia genetics began to emerge. The period from the 1960s to the 1980s represented about 40 tilapia generations of missed opportunity for genetic improvement.

This impact evaluation study (IES) was designed to assess the impacts of the development of genetically improved farmed tilapia (GIFT) and their dissemination in selected countries. The Asian Development Bank (ADB) supported the R&D and dissemination of GIFT by providing technical assistance (TA) from 1988 to 1997.[1] This TA supported an international R&D effort that was coordinated and executed by the International Center for Living Aquatic Resources Management (ICLARM, now the WorldFish Center) and funded primarily by ADB, ICLARM, the United Nations Development Programme (UNDP), and participating national research partners, with contributions from funding agencies in the form of parallel financing.

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[1] TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988, implemented from 1988 to 1992; TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA)*, for $600,000, approved on 14 December 1993, implemented from 1994 to 1997.

Nile tilapia was the species chosen for this strategic research because of its importance in freshwater aquaculture and its short generation time of about 6 months, which would allow rapid results of breeding experiments and rapid dissemination of improved breeds. The plan was to develop GIFT using conventional breeding methods, without recourse to genetic modification by gene transfer. The development and dissemination of GIFT were designed to address five immediate objectives: (i) to develop improved breeds of Nile tilapia; (ii) to build the capacity of national institutions in aquaculture genetics research; (iii) to disseminate GIFT; (iv) to carry out genetic, socioeconomic, and environmental evaluation of GIFT; and (v) to facilitate the development of national tilapia breeding programs. These immediate objectives were framed in the context of long-term strengthening of national research capacity for continued genetic improvement of tilapia, and for implementing national fish breeding programs. The availability of improved tilapia breeds was expected to improve profitability for fish farmers and to increase the availability of animal protein for rural and urban consumers, including the poor.

The 10-year (1988–1997) R&D effort evolved over time in the manner of such initiatives that are not designed from the outset as a series of predetermined interventions. The purposes of the IES were to (i) probe catalytic effects of R&D and dissemination of GIFT; (ii) illustrate the different types of outcomes and impacts that GIFT initiatives have had in selected countries, including the evolution of partnerships and collaborative efforts; (iii) distill pertinent lessons from the initiatives; (iv) highlight major issues and opportunities relevant to R&D and dissemination of GIFT; and (v) provide recommendations for further R&D and dissemination of GIFT for greater relevance to poverty reduction. The following are the major findings of the study.

The development of GIFT has demonstrated to participating national partners that rapid genetic improvement of farmed tilapia is possible through selective breeding. In Bangladesh, Fiji Islands, Philippines, Thailand, and Viet Nam, national tilapia breeding programs and related tilapia genetics research are now based mainly or exclusively on GIFT or GIFT-derived tilapia strains using approaches based on selective breeding. GIFT-related methods have also been used for genetic improvement of other species of farmed fish.

ADB's contribution to the development of GIFT has served as a major catalyst in associated R&D investments. Without the ADB TA and related funding from UNDP and others, aquaculture genetics research in general and tilapia genetic improvement research in

particular would probably have been delayed by at least 10 years in the Asia and Pacific region.

Networks among countries at various levels accelerated the dissemination of GIFT, GIFT methods, and information on improved tilapia farming practices. These networks have been complemented by diverse dissemination channels that have helped to strengthen the linkage between genetics research and distribution of improved tilapia breeds to farmers. Fish seed traders have also served as dissemination channels, and have helped to link tilapia seed producers to customers. Farmer-to-farmer contacts and social networks among members of rural communities have also hastened the spread of GIFT and of tilapia farming practices.

The development and dissemination of GIFT have facilitated the expansion of public-private partnerships in varying degrees. Key areas of collaboration that have emerged include seed production, seed distribution, extension, financing for farm operations, and setting directions for the tilapia sector.

The development and dissemination of GIFT and GIFT-related methods have contributed substantially to raising public investment in the application of genetics to aquaculture in general and to tilapia farming in particular in the Asia and Pacific region. Expansion of tilapia farming has become one of the main pillars for increasing national fish supply in the Philippines, Thailand, and Viet Nam. Related policy and planning documents give high importance to fish genetic improvement and breeding programs. National plans for tilapia, developed subsequent to the dissemination and use of GIFT, call for substantial increases in farmed tilapia production. Such plans have considered both expanding domestic demand for tilapia and modest potential exports.

The substantial impacts of GIFT and GIFT-derived strains on farmed tilapia production are evident from their increasing shares in tilapia seed supply. The survey commissioned under this study found that in 2003, GIFT and GIFT-derived strains accounted for 68% of the total tilapia seed produced in the Philippines, 46% in Thailand, and an estimated 17% in Viet Nam. The overall contribution of GIFT and GIFT-derived strains in Viet Nam is expected to increase substantially because of a GIFT-based national tilapia breeding program. In Bangladesh, GIFT have yet to make a significant contribution to national freshwater aquaculture production, but this is likely to change, because the availability and popularity of farmed tilapia are increasing. In the People's Republic of China, GIFT have seen extensive use in research to improve performance traits of farmed tilapia.

The introduction and dissemination of GIFT have generated significant rural income and employment. Tilapia farming provides an attractive livelihood for hatchery operators and fish farmers. For example, at least 280,000 people in the Philippines and 200,000 people in Thailand, inclusive of their families, directly and indirectly benefit annually from employment generated by tilapia farming alone. The poor and small-scale farmers are among those who benefit from employment in tilapia farming and its associated activities.

Fish is particularly important in the diet of people in the world's poorest countries, supplying more than 50% of their animal protein intake. Attention to fish production and consumption is vital to achieving one of the Millennium Development Goals—that of eradicating hunger and reducing the incidence of malnutrition. Tilapia contributed to the nutrition of fish consumers. Tilapia has been a more affordable source of protein than pork, chicken, and other sources of animal protein. The expanding use of GIFT indicates the current and future contributions of tilapia to human nutrition of fish consumers, including rural and urban poor in countries where tilapia are farmed.

The development and dissemination of GIFT have proven to be meaningful investments with attractive economic returns. The WorldFish Center estimated that the economic internal rate of return on investments in GIFT development and dissemination was more than 70% over a period from 1988 to 2010, with an estimated net present value of $368 million in constant 2001 prices.

The development and dissemination of GIFT inevitably raise questions as to whether they, and any modifications that they might initiate in farming methods, could cause adverse impacts on the natural environment and biodiversity. All international introductions of tilapia during the TA were planned and implemented under the highly precautionary policies of ICLARM. None was a first introduction to any country of Nile tilapia as an alien species, and strict quarantine measures were applied. To date, there have been no reports of adverse impacts of GIFT and GIFT-derived Nile tilapia on the environment and on biodiversity.

The IES identified several major lessons:

(i) R&D in tilapia genetics and dissemination of improved tilapia breeds require long-term and sustained investments. The development of GIFT and their uptake in national tilapia breeding programs took at least 10 years. Dissemination of improved tilapia breeds then took place rapidly and generated substantial impacts in

countries that participated in this effort. Once developed, improved tilapia breeds and sustained national tilapia breeding programs can significantly and rapidly improve the yields and productivity of tilapia farms.

(ii) The development and dissemination of GIFT have shown that selective breeding is a feasible and cost-effective approach to the genetic improvement of tropical farmed fish. GIFT were developed without the need for any application of controversial biotechnology or genetic modification.

(iii) The GIFT experience has shown that systematic assessments of the performance of genetically improved farmed fish under diverse conditions must precede their commercial production. Multidisciplinary expertise is imperative for assessing economic viability, social acceptability, and environmental compatibility.

(iv) Multilevel partnerships and broad-based networks that are driven by common objectives and mutual commitments are highly valuable mechanisms for developing and disseminating genetically improved farmed fish. Global partnerships, along with national research and seed and broodstock distribution networks, have accelerated the wide use of GIFT and GIFT methods and the spread of improved hatchery and farming practices.

(v) ADB has supported pioneering efforts for the development and dissemination of GIFT by providing TA. ADB's TA has been instrumental in catalyzing the development of broader multinational partnerships and networks, and in galvanizing further support to promote and recognize the importance of genetic improvement of farmed fish and national fish breeding programs for the development of aquaculture.

(vi) Key enabling conditions must be in place in a country for the development and dissemination of genetically improved farmed fish to succeed and to be sustainable. These include (a) capabilities in fish genetics research; (b) resources and commitments for national fish breeding programs; (c) networks and partnerships for production and distribution of fish seed; (d) market-driven demand and attractive returns from fish farming; (e) supportive policies, facilities, and infrastructure for fish farming; and (f) biosafety and environmental safeguards.

(vii) To date, the development and dissemination of GIFT, GIFT-derived strains, and other Nile tilapia have not caused any significant adverse impacts on existing aquaculture or on the natural environment and biodiversity in the Asia and Pacific region. However, the region has a wealth of freshwater biodiversity and habitats, and adequate areas containing this natural heritage should, where possible, be kept off limits to aquaculture, whether of native or alien species, including tilapia. Such areas would contain the wild genetic resources for future breeding programs of Asian farmed fish, and would serve as in situ gene banks for this purpose, in addition to their conservation and amenity values.

Based on the experience of development and dissemination of GIFT and the resulting outcomes and impacts, the following are recommended:

(i) ADB should support further collaborative efforts to (a) identify additional opportunities for the application of genetics in Asian-Pacific aquaculture; and (b) support R&D on fish breeding, especially for species that can be bred for desirable performance traits over short generation times. This recommendation is consistent with the ADB's Policy on Fisheries.

(ii) ADB should consider providing further support to its developing member countries to establish self-sustaining national tilapia breeding programs and related research to (a) improve performance of tilapia broodstock and farmed strains; (b) promote appropriate dissemination channels; and (c) enhance market intermediary mechanisms to ensure that farmers, including the poor, have wider access to affordable seed.

(iii) Future efforts are required to promote (a) public-private partnerships in tilapia research and information exchange, (b) commercial alliances and partnerships in seed production and distribution, and (c) tilapia marketing to meet growing domestic demand and potential exports. To avoid potential conflicts of interest between public and private sectors in tilapia seed supply, concerned parties must carefully delineate and comply with their respective roles. Otherwise, the public sector may stifle the interests of the private sector.

(iv) The genetic improvement of tilapia and the expansion of breeding for tilapia farming should be undertaken in

parallel with conservation of aquatic biodiversity and genetic resources. Consequently, all countries farming tilapia should strive to keep some of their waters that contain important aquatic biodiversity and genetic resources off-limits for aquaculture and isolated from all possible contact with farmed fish.

(v) Tilapia farming is undergoing a major expansion worldwide and is contributing significantly to food security, incomes, and employment. However, tilapia farming faces unavoidable climatic risks, and is further jeopardized by ineffective quarantine and by irresponsible fish introductions, releases, and escapes. Effective biosafety measures to safeguard tilapia farming and reliable arrangements for the certification of tilapia strains are priorities for policymakers to consider and for national programs and tilapia farming entities to implement. All countries farming tilapia should recognize these risks, and take steps to encourage all stakeholders to safeguard the future of tilapia farming as it expands.

BACKGROUND

GLOBAL CONTEXT OF AQUACULTURE DEVELOPMENT

Fish is particularly important in the diet of people in the world's poorest countries, supplying more than 50% of their animal protein intake.[1] Attention to fish production and consumption is vital to achieving one of the Millennium Development Goals—that of eradicating hunger. The target is to halve, between 1990 and 2015, the number of undernourished people from 800 million to 400 million.[2] Enhancing access of the poor to the food they need and creating livelihood opportunities to hasten their exit from poverty are part of the current fight against global hunger and extreme poverty.

Aquaculture has been growing more rapidly than any other animal food-producing sector in the world. During 1970–2000, global aquaculture production grew at an average annual rate of 9.2%, compared with only 1.4% for capture fisheries and 2.8% for terrestrial farmed meat production.[3] In 2000, global aquaculture production was 45.7 million metric tons (t), valued at $56.5 billion. Finfish accounted for 23 million t, or about half of total aquaculture production. In the past three decades, aquaculture has expanded, intensified, and made major technological advances. Most of the world's recent increases in per capita food fish supply have been obtained from aquaculture. Worldwide, more than 1 billion people rely on fish as an important source of animal protein, healthy lipids, and essential micronutrients.

With increasing popularity among consumers, tilapia[4] have become the world's second most popular farmed fish, after carps. Global production of farmed tilapia exceeded 1.5 million t in 2003, valued at about $2.0 billion.[5] Tilapia are farmed in at least 85

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1 World Bank. 2004. *Saving Fish and Fishers*. Washington, DC.

2 Millennium Development Goals. Available: http://www.undp.org/mdg

3 FAO. 2002. *The State of World Fisheries and Aquaculture*. Rome: Food and Agriculture Organization of the United Nations. 124 p. Available: http://www.fao.org/docrep

4 Tilapia feed naturally on phytoplankton and detritus. In aquaculture, tilapia are regarded as opportunistic omnivores and herbivores, just like the world's principal farmed livestock. See: Beveridge, Malcolm, and D. Baird. 2000. Diet, Feeding and Physiology. In *Tilapias: Biology and Exploitation*, edited by Malcolm Beveridge and Brendan McAndrew. Dordrecht: Kluwer Academic Publishers. p. 59–87.

5 Fitzsimmons, Kevin. 2004. Development of New Products and Markets for the Global Tilapia Trade. Paper presented at the Sixth International Symposium on Tilapia in

countries, with most production coming from the developing countries of Asia and Latin America. The global supply of farmed tilapia surged in the 1990s and early 2000s, largely due to genetic improvements through conventional breeding methods, widespread introductions of improved tilapia breeds, feed supply availability, effective management of reproduction through sex reversal and hybridization,[6] and expansion of consumer markets. Asia and Latin America dominated the world's top producers of farmed tilapia: People's Republic of China (PRC); Taipei,China; Philippines; Mexico; Thailand; Brazil; Egypt; Indonesia; Colombia; Cuba; and Ecuador. Together, these accounted for 93% of farmed tilapia, of which production in Asia made up 70%; Latin America, 19%; and Egypt, 4%. International trade of tilapia is limited but growing, especially in Asia, Latin America, and the United States (US).

RELEVANCE OF GENETIC IMPROVEMENT IN AQUACULTURE

Genetics in Aquaculture. Unlike crops and livestock, most farmed fish have very short histories of domestication and genetic improvement, and many still resemble closely their wild relatives. Asia provides more than 80% of the world's farmed fish. Until relatively recently, most were grown from wild fish seed (fry and fingerlings) or from the progeny of captive spawners (called broodstock) that were managed with little or no application of genetics. Production of fish seed in hatcheries and the ability to grow successive generations of broodstock to sexual maturity began in the 1970s for most Chinese and Indian carps and in the 1980s and 1990s, respectively, for farmed shrimp (*Penaeidae*) and milkfish (*Chanos chanos).* The world's first International Symposium on Genetics in Aquaculture was convened in 1982.[7] Up to the mid-1980s, most aquaculture research and development (R&D) was targeted at seed production technology and improved fish husbandry rather than at genetic improvement.

Tilapia in Asia. There are about 70 known species of tilapia, of which 10 have been used in aquaculture. All tilapia are native to

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Aquaculture, 12–16 September 2004, Philippine International Convention Center, Manila, Philippines.

6 Shelton, William. 2002. Tilapia Culture in the 21st Century. In *Tilapia Farming in the 21st Century*, edited by Rafael Guerrero III and Ma. Rizalina Guerrero-del Castillo. Los Baños, Philippines: Philippine Fisheries Association, Inc.

7 Pullin, Roger. 1982. Genetics Undervalued. International Symposium on Genetics in Aquaculture. *Marine Policy* 6 (4): 345–347.

Africa. The Asia and Pacific region has no native tilapia and no native fish species with comparable attributes to tilapia for aquaculture. The first tilapia introduced from Africa to Asia were small populations of the Mozambique tilapia (*Oreochromis mossambicus*), sent from East Africa to Indonesia as aquarium fish. In 1939, *O. mossambicus* was first used in fresh- and brackishwater fishponds in Java. During the late 1940s and 1950s, *O. mossambicus* was disseminated throughout the Asia and Pacific region, but with little concern for the genetic consequences of using very small founder populations. For example, the founder stock sent from Thailand to the Philippines in 1949 consisted of just three males and one female.[8] *O. mossambicus* was an obvious choice of species as Asia's first farmed tilapia because of its availability in the region. However, it turned out to be a poor choice. *O. mossambicus* has slow growth rates, and it matures at a small size, leading to overcrowding of fishponds with small fish. Moreover, *O. mossambicus* became widely established in the Asia and Pacific region as an alien, invasive, and sometimes problematic species in natural waters and in fishponds used to farm shrimp and milkfish. Consequently, tilapia farming in Asia failed to develop until the Nile tilapia (*O. niloticus*), a faster growing and more manageable species than *O. mossambicus*, was introduced from Africa in the 1960s. During the 1960s, most farmed populations of Nile tilapia in Asia were descendants of a single introduction from Egypt to Japan in 1962. Thereafter, up to the early 1980s, there were occasional introductions from Israel, mainly to Southeast Asia, of farmed Nile tilapia strains that had originated in Ghana and Uganda.

Nile tilapia farming in Southeast Asia began to prosper in the 1970s, particularly in the Philippines and Thailand. There were contemporary, regionwide advances in tilapia hatchery technology and in pond and cage husbandry. Technology was developed to produce all male, sex-reversed tilapia (SRT) seed, because male tilapia grow faster than females, and the unwanted reproduction, overcrowding, and harvest of undersized fish are avoided.[9] These advances boosted production of farmed tilapia and masked the lack of attention to their genetics in the 1970s and 1980s. As an indication of this, up to the late 1980s, most aquaculture researchers described their tilapia populations only by species name, with little or no documentation about their provenance and breeding histories. This would have been unthinkable in contemporary terrestrial crop

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[8] Lowe-McConnell, Rosemary. 2000. The Roles of Tilapia in Ecosystems. In *Tilapias: Biology and Exploitation*, edited by Malcolm Beveridge and Brendan McAndrew. Dordrecht: Kluwer Academic Publishers. p. 129–162.

[9] SRT receive, for a short period, feeds containing methyltestosterone, posing no risks to consumers.

research. During the 1980s, however, some consequences of the lack of attention to tilapia genetics were beginning to emerge. In the Philippines, for example, disappointing tilapia harvests were attributed largely to inbreeding and to accidental hybridization with *O. mossambicus* that had become established in adjacent waters.[10] The period from the 1960s to the 1980s represented about 40 tilapia generations of missed opportunity for genetic improvement.

Strategic R&D for Genetic Improvement of Farmed Tilapia. From its incorporation in the Philippines in 1977, the International Center for Living Aquatic Resources Management (ICLARM; now the WorldFish Center, with headquarters in Penang, Malaysia) focused its strategic inland aquaculture research and publications on tilapia farming.[11] In the Philippines, ICLARM established close and enduring partnerships for tilapia research with the Freshwater Aquaculture Center (FAC) of Central Luzon State University (CLSU) and the National Freshwater Fisheries Technology Center (NFFTC) of the Bureau of Fisheries and Aquatic Resources (BFAR). In 1987, ICLARM convened a pivotal workshop for tilapia researchers from Africa, Asia, Europe, Israel, and North America, at which the urgent need for genetic improvement of farmed tilapia in Asia was confirmed.[12] The International Development Research Centre of Canada (IDRC) was also then supporting a variety of aquaculture genetics research projects in Asia, linked by an effective, though short-lived, regional network. ICLARM and the Institute for Aquaculture Research, Norway (AKVAFORSK) proposed a large and highly focused research effort toward genetic improvement of Nile tilapia[13] by selective breeding, following the approach pioneered in Norway for genetic improvement of farmed Atlantic salmon (*Salmo salar).*[14] Detailed plans for the genetic development of farmed tilapia were formulated by AKVAFORSK, BFAR, FAC, ICLARM, and the Marine Science Institute of the University of the Philippines, and peer reviewed by 25

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[10] Macaranas, Julie, Nobuhiku Tanigichi, Liza Agustin, Maria-Josefa Pante, Ambekar Eknath, and Roger Pullin. 1986. Electrophoretic Evidence for Extensive Hybrid Gene Introgression into Commercial *Oreochromis niloticus* (L.) in the Philippines. *Aquaculture and Fisheries Management* 17: 249–258.

[11] For example: Pullin, Roger and Rosemary Lowe-McConnell, eds. 1982. The Biology and Culture of Tilapias. *ICLARM Conference Proceedings 7*. Manila.

[12] Pullin, Roger, ed. 1988. Tilapia Genetic Resources for Aquaculture. *ICLARM Conference Proceedings* 16. Manila.

[13] Gjedrem, Trygve, and Roger Pullin. 1986. *A New Breeding Program for the Development of Tilapia Culture in Developing Countries. Report to the Rockefeller Foundation*. Makati City: International Center for Living Aquatic Resources Management.

[14] Gjedrem, Trygve. 1985. Improvement of Productivity through Breeding Schemes. *Geojournal* 10 (3): 233–241.

of the world's leading fish geneticists. R&D and dissemination of genetically improved farmed tilapia (GIFT) were proposed not only to benefit tilapia farming per se, but more generally to demonstrate potential returns from the application of genetics in tropical aquaculture. Nile tilapia was the species chosen for this strategic research because of its (i) importance as the most commonly farmed tilapia species in freshwater aquaculture;[15] and (ii) relatively short generation time of about 6 months, which would allow rapid results from breeding experiments and rapid dissemination of improved breeds. The plan was to develop GIFT using conventional breeding methods, without recourse to genetic modification by gene transfer.

Research and Development Objectives. R&D and dissemination of GIFT were designed to address five immediate objectives: (i) to develop improved breeds of Nile tilapia; (ii) to build the capacity of national institutions in aquaculture genetics research; (iii) to disseminate GIFT; (iv) to carry out genetic, socioeconomic, and environmental evaluation of GIFT; and (v) to facilitate the development of national tilapia breeding programs. These immediate objectives were framed in the context of long-term strengthening of national research capacity for continued genetic improvement of GIFT and for implementing national fish breeding programs, and to promote environment-friendly fish farming. Unlike carnivorous fish, tilapia feed low in the food chain, as do the world's domestic livestock.[16] Tilapia can rely on natural feed produced in warm water ponds, capitalizing on sunlight and photosynthesis of phytoplankton, and utilizing organic and inorganic fertilizers. Improved tilapia breeds were expected to improve profitability for fish farmers and increase the availability of animal protein for rural and urban consumers, including the poor.

THE ASIAN DEVELOPMENT BANK'S ROLE

The Asian Development Bank (ADB) supported the R&D and dissemination of GIFT by providing technical assistance (TA) from 1988 to 1997.[17] This TA supported an international R&D effort that was

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[15] ADB. 2004. *Special Evaluation Study on Small-Scale Freshwater Rural Aquaculture Development for Poverty Reduction*. Manila.

[16] Many of the fish species farmed in Asia, including carps, tilapia, shrimp, and mollusks, feed low in the food chain as herbivores or detritivores or on relatively low-cost feeds.

[17] (i) TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988 and implemented from 1988 to 1992.
(ii) TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA)*, for $600,000, approved on 14 December 1993, implemented from 1994 to 1997.

coordinated and executed by ICLARM and funded by ADB, ICLARM, the United Nations Development Programme (UNDP), and participating national research partners.[18] TA for the Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA, footnote 17[ii]) was implemented in 1994–1997, funded by ADB. Contributions from funding agencies were in the form of parallel financing. The 10-year (1988–1997) R&D evolved over time in the manner of such initiatives, which are not designed from the outset as a series of predetermined interventions. Figure 1 illustrates ADB's role in the development and dissemination of GIFT.

Implementation Arrangements and Aid Coordination. ICLARM was the implementing agency throughout the TA for the development and dissemination of GIFT (footnote 18). ICLARM's development partners and their respective roles were (i) AKVAFORSK for quantitative genetics, (ii) NFFTC and FAC for tilapia breeding and farming, and (iii) the Marine Science Institute of the University of the Philippines for genetic characterization.[19] Advice and practical help were received from many countries, including Belgium, Canada, Egypt, Germany, Ghana, Israel, Kenya, Sénégal, United Kingdom (UK), and US. With participation of ADB, ICLARM and UNDP, tripartite reviews as well as an external advisory panel of eminent aquaculture scientists were conducted annually to review progress of these R&D collaborative efforts. For germplasm collection of Nile tilapia across from its natural range in Egypt, Ghana, Kenya, and Sénégal, and shipment to the Philippines, principal assistance was received from the Institute of Aquatic Biology (now the Water Research Institute), Accra, Ghana; Baobab Farms, Mombasa, Kenya; the Musée Royale de l'Afrique Centrale, Tervuren, Belgium; the Suez Canal University,

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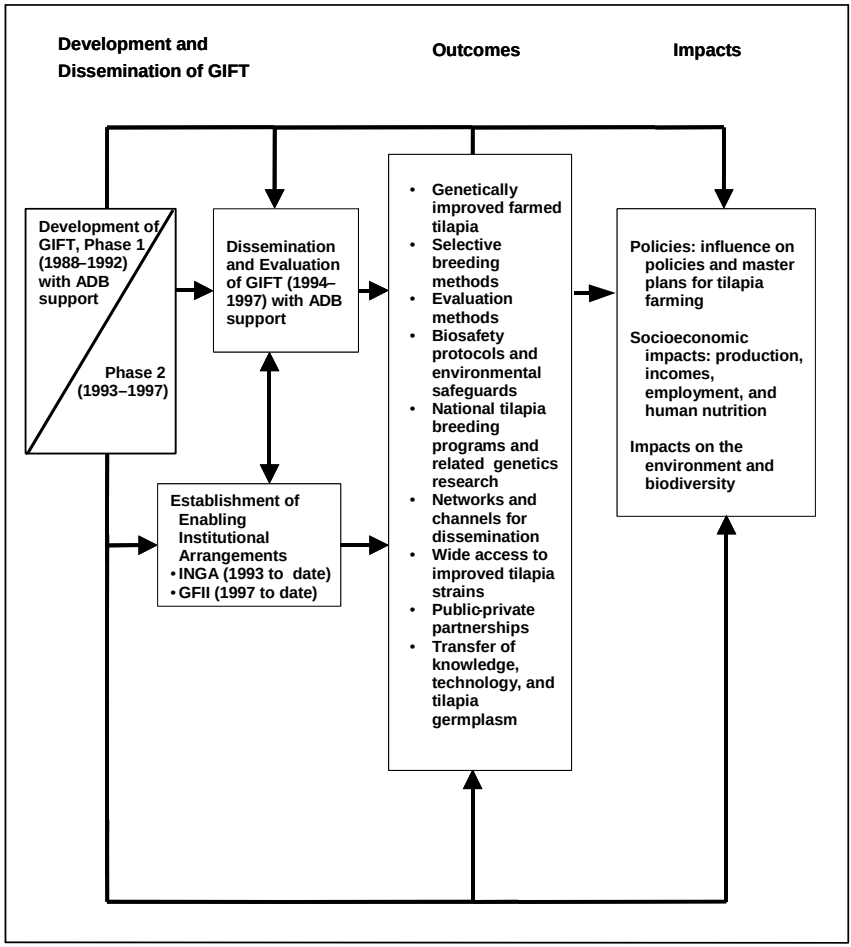
[18] ADB provided $475,000 for TA for the first phase of the development of GIFT in 1988–1992 (footnote 17[i]), while UNDP provided $525,000 and ICLARM and its research partners contributed in-kind support. TA for the Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA, footnote 17[ii]) was implemented in 1994–1997, funded principally by ADB ($600,000) while ICLARM contributed $302,205 from its core funds. In 1993–1997, UNDP provided a further $4,307,690 for a second phase of development of GIFT and related research partnerships and networking, while ICLARM contributed $809,029 from its core funds. The national program partners (Bangladesh, PRC, Philippines, Thailand, and Viet Nam) of DEGITA contributed in total about $300,000 from their national program budgets. Overall, ADB provided $1,075,000 (14.7%) of the combined financial resources of $7,318,924 made available during 1988–1997, excluding in-kind contributions.

[19] Gupta, Modadugu, and Belen Acosta. 2001. Development of Global Partnerships for Fish Genetics Research—A Success Story. Paper prepared for the Technical Workshop on Methodologies, Organization and Management of Global Partnership Programs, 9–10 October 2001, International Fund for Agricultural Development, Rome, Italy.

Egypt; and the University of Hamburg, Germany. Advice on quarantine procedures was received from Canadian researchers supported by IDRC.

Figure 1: Outcomes and Impacts of the Development and Dissemination of Genetically Improved Farmed Tilapia (GIFT)



GFII = Genetic Improvement of Farmed Tilapia Foundation International Incorporated, INGA = International Network on Genetics in Aquaculture.

ICLARM implemented DEGITA in collaboration with the Bangladesh Fisheries Research Institute, the National Aquaculture Genetics Research Institute (now the Aquatic Animal Genetics Research and Development Institute) of Thailand, NFFTC, Shanghai Fisheries University, and Research Institutes for Aquaculture (Nos. 1 and 2) of Viet Nam. The development of GIFT and DEGITA

necessitated the improvement of research facilities and support for their operations at all partner institutes. The improved facilities in the Philippines, where GIFT were developed, included a quarantine unit, new ponds and tanks, laboratory and field equipment, and a tilapia gene bank comprising collections of broodstock and cryopreserved sperm samples. Throughout the development of GIFT, AKVAFORSK and ICLARM staff provided on-the-job and formal training for Philippine national program researchers and technicians, principally on quantitative genetics, fish breeding, and statistical methods. Throughout DEGITA, training was provided to technical staff and farmers for on-station and participatory, on-farm research toward genetic improvement of tilapia and dissemination of improved tilapia strains.[20]

[20] In addition to numerous trainees in the Philippines as host country for the development of GIFT and the source for dissemination of GIFT through DEGITA, the numbers of persons trained were, by country: Bangladesh, 66; PRC, 14; Thailand, 70; and Viet Nam, 11.

PURPOSE AND METHOD OF EVALUATION

PURPOSE OF THE STUDY

This impact evaluation study (IES) was designed to assess the impacts of R&D and dissemination of GIFT in selected countries. It sought to (i) probe catalytic effects of R&D and dissemination of GIFT; (ii) illustrate the different types of outcomes and impacts that GIFT initiatives have had in selected countries, including partnerships and collaborative efforts; (iii) distill pertinent lessons from the initiatives; (iv) highlight major issues and opportunities relevant to R&D and dissemination of GIFT; and (v) provide recommendations for further R&D and dissemination of GIFT for greater relevance for poverty reduction.

METHODOLOGY

The IES reviews the evolution and achievements of the ADB-financed TA chronologically to identify the catalytic effects of R&D and dissemination of GIFT. It used a case study approach to analyze various dimensions of the overall outcomes and impacts of R&D and dissemination of GIFT in Bangladesh, Philippines, Thailand, and Viet Nam.

The IES used both qualitative and quantitative methods of data collection and inquiry, including (i) review of relevant reports and publications, (ii) secondary data analysis, (iii) key informant interviews, and (iv) primary data collection through surveys of tilapia hatcheries in the Philippines and Thailand. Methods and sources of these surveys of tilapia hatcheries are detailed in this report in the relevant country case studies for the Philippines and Thailand, respectively. Presurvey activities included reconnaissance, rapid rural appraisal, pretesting and refinement of survey instruments, preparation of sampling frames, and sampling of respondents. The Statistical Package for Social Sciences was used to generate descriptive statistics and inferential statistics for analyzing survey data collected from the hatcheries in the Philippines and Thailand. The survey was based on recall by respondents rather than on documented baseline information. The IES also draws on relevant findings of and case studies prepared for the recent ADB Special

Evaluation Study on Small-Scale Freshwater Rural Aquaculture Development for Poverty Reduction (footnote 15). The IES was undertaken from December 2003 to September 2004, benefiting from close consultations with the WorldFish Center, and with relevant national partner research institutes for the preparation of the country case studies in Bangladesh, Philippines, Thailand, and Viet Nam.

This report makes no reference to specifically numbered generations of selectively bred GIFT because there is no standard nomenclature for these among breeders and researchers. All GIFT are regarded here as a genetically improved breed of Nile tilapia. The Nile tilapia strains that were bred and disseminated through the TA are called GIFT, as are any tilapia bred subsequently using only GIFT genetic material. Tilapia bred by crossbreeding GIFT and other tilapia are called GIFT-derived.

REPORT STRUCTURE

Chapter III discusses key features of genetic improvement of farmed tilapia. Chapter IV summarizes key outcomes and related issues concerning the development and dissemination of GIFT. Chapter V summarizes impacts of GIFT operations on (i) policies and plans for expansion of tilapia farming, (ii) production of farmed tilapia, (iii) incomes of hatchery operators and farmers, (iv) employment, (v) human nutrition, and (vi) environment and biodiversity. Chapter VI draws pertinent lessons, and Chapter VII provides recommendations for future action relevant to the application of genetics in aquaculture and for the dissemination of GIFT to be more relevant for poverty reduction.

Complementary information channels for further development and dissemination of GIFT, specifically on the International Network on Genetics in Aquaculture (INGA) and the Genetic Improvement of Farmed Tilapia Foundation International Incorporated (GFII), are provided in Appendix 1. Impacts of GIFT in its host country of development, the Philippines, are described in Appendix 2. Impacts of GIFT in other countries are presented in Appendixes 3 (Bangladesh), 4 (Thailand), and 5 (Viet Nam).

KEY FEATURES OF GENETIC IMPROVEMENT OF FARMED TILAPIA

CHOICE OF PERFORMANCE TRAITS FOR GENETIC IMPROVEMENT

General Considerations. The developers of GIFT were faced with choosing one or more important tilapia performance traits for which to seek improvement. This choice was critical not only for breeding GIFT but also, and arguably more importantly, for demonstrating methods that could be applied widely in tropical aquaculture.

Survival. In tilapia farming, as in most farming, the most important performance trait is survival. A farmer needs to be able to harvest as many as possible of the fish he or she bought as seed. However, survival to harvest depends on a multitude of genetic and environmental factors and on interactions among these factors. Throughout the history of tropical aquaculture, many farmers have overstocked their ponds and cages as a countermeasure against unpredictable, and sometimes high, fish mortalities. This overstocking itself has often contributed to such mortalities and has resulted in wasted expenditure on seed and feed and in lost revenues because of reduced harvests. Researching the genetic determinants of fish survival on-farm is difficult. Fortunately, most tilapia are hardy fish, and they usually have high survival in diverse farm environments within their natural tolerance ranges for temperature and salinity. Up to the 1990s, tilapia farming remained remarkably free from serious disease problems.[21] These factors make it difficult to attempt to improve tilapia survival by selective breeding. However, it was also essential for the developers of GIFT to determine whether selective breeding can have adverse consequences for survival. GIFT developers monitored the survival of different tilapia strains under well-defined conditions, on-station and on-farm, rather than attempting to select for survival.

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[21] Pullin, Roger, and Jay Maclean. 1992. Analysis of Research for the Development of Tilapia Farming—An Interdisciplinary Approach Is Lacking. *Netherlands Journal of Zoology* 24(2/3): 512–522.

Growth. Most tilapia farmers consider fast growth from seed to harvest size to be the most important performance trait, along with high survival rate. The efficiency with which a fish converts feed to body mass is also an important consideration. However, for the majority of tilapia farming systems prevalent in Asia when the development of GIFT started, growing fish quickly to harvest size, even with ad libitum feeding, was the overriding concern. These farming systems comprised mainly fishponds, fertilized to produce natural plankton as feeds and also supplied with supplemental feed, and cages in which fish were usually supplied with more complete formulated feeds. In these situations, there is sometimes a tendency to overfeed fish in the belief that this will lead to increased harvests. This situation complicates estimation of feed conversion efficiency. Methods for the genetic improvement of feed conversion efficiency in farmed fish were not available when GIFT were developed and are still under development.[22]

Growth of livestock and some fish species (footnote 14) has been readily improved by selective breeding. However, growth rate is a complex trait to measure, because the growth rates of fish change during their development from juveniles to adults. For the development of GIFT, harvest weight at 90 or 120 days was chosen as the trait to be improved. This was a reasonable choice as an indicator of overall growth rate, given that historical harvest sizes for farmed tilapia in Asia had ranged from about 100 grams (g) to about 350 g, from cropping cycles of up to 9 months.[23] After 90 or 120 days, any farmed tilapia would be expected to have a harvest weight indicative of its growth rate during its main phase of growth. These were also convenient periods for experimentation: long enough to show growth differences among tilapia strains and short enough for multiple trials and progress in selection.

Other Traits. Delayed maturation in Nile tilapia production stocks could be viewed as advantageous by some tilapia farmers, because it would give them the option to grow both male and female fish, not just all male SRT (footnote 9), to larger sizes at harvest before they matured and spawned. Conversely, tilapia seed producers would not normally welcome delayed maturation because it would take longer for their broodstock to start spawning. Later maturation might, however, be acceptable to some seed producers if the result were female fish that produced larger and more viable eggs and fry

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[22] Doupé, Robert, and Alan Lymbery. 2003. Toward the Genetic Improvement of Feed Conversion Efficiency in Fish. *Journal of the World Aquaculture Society* 34(3): 245–254.

[23] For example: Smith, Ian, Enriqueta Torres, and Elvira Tan, eds. 1985. Philippine Tilapia Economics. *ICLARM Conference Proceedings* 12. Manila.

that could be sold at higher prices—although a fish producing larger eggs would normally produce fewer eggs. Given these considerations, age and size at maturation are difficult traits in tilapia breeding. They are influenced by multiple genetic and environmental factors and by interactions among these factors.

Traits for Improvement. Developers of GIFT envisaged breeding a general purpose, faster growing strain of Nile tilapia suitable for a wide range of farm environments, with sufficient genetic variability for subsequent selection for other traits. Therefore, the only trait continuously targeted for improvement was harvest weight at 90 or 120 days. There were some limited attempts to select for later maturation but, for the most part, maturation and spawning were simply monitored, along with survival.

ACQUIRING AND ASSESSING DIVERSE TILAPIA GERMPLASM

Acquisition of Wild Nile Tilapia Germplasm from Africa. In 1988 and 1989, ICLARM and its partners and helpers collected germplasm of four wild strains of Nile tilapia across its natural range through visits to Egypt, Ghana, Kenya, and Sénégal. More than 2,000 fish were shipped, some via intermediate holding facilities at the University of Hamburg, to a purpose-built quarantine facility at NFFTC. The collection and shipment of tilapia germplasm involved collaboration and coordination of international assistance (para. 10). These introductions were the first direct and well-documented acquisitions of wild tilapia germplasm in Asia since 1962, apart from one other introduction of Nile tilapia from Sudan to the PRC in 1978 (footnote 12).

Assessing Performance of African Wild and Asian Farmed Nile Tilapia Strains. The weights at harvest after 90 days were compared among eight Nile tilapia strains: the first generation progeny of the newly introduced four African wild strains and progeny obtained from four existing Asian strains farmed in the Philippines. The four Asian farmed strains were the widely farmed Israel strain and three others named after their most recent origins prior to introduction to the Philippines: Singapore, "taiwan" (both probably derived from introductions from Israel), and Thailand (probably of Egyptian origin). Tagged fish from all eight strains were stocked communally in 11 different farm environments including ponds, cages, and rice-fish systems, as well as lowland and upland locations. This required the tagging of 11,000 individual fish and was the largest experiment of its kind ever undertaken in Asia. Three of

the African wild strains (Egypt, Kenya, and Sénégal) grew consistently as well as or faster than the Asian farmed strains across all test environments.[24] These results affirmed that there were significant genetic determinants of growth performance among these diverse Nile tilapia strains. It was also evident that, in these initial trials, wild tilapia had grown to larger weights at harvest than had tilapia descended from Asian stocks that had been farmed for more than 20 years.

BREEDING STRATEGY

Selective Breeding versus Crossbreeding. Selective breeding of farmed plants and animals (for fast growth, disease resistance, etc.) focuses on commercially desirable traits that are moderately or highly heritable. The best performers are chosen as breeders in successive generations. The main alternative strategy to selective breeding is crossbreeding, also called hybridization, which takes advantage of the unpredictable but sometimes considerably improved performance exhibited by hybrid progeny compared with that of their parents. This improved performance of crossbreeds is known as hybrid vigor. Unlike selective breeding, in which incremental genetic improvements are achieved with each successive generation, crossbreeding generates a one-time improvement, which must usually be regenerated every time seed is mass produced. This means keeping two separate sets of parental broodstock.

From the history of genetic improvement in aquaculture, particularly that for Atlantic salmon in Norway (footnote 14), ICLARM and its partners had anticipated that selective breeding would be the more appropriate strategy for the development of GIFT. However, it was also necessary to explore the possible advantages of crossbreeding among the eight assembled Nile tilapia strains. This required another experiment on a scale never before undertaken in Asian aquaculture. The weights at harvest after 90 days of all 64 possible pure- and crossbreeds among and within the four African and four Asian strains were measured in different test environments, again including ponds and cages as well as lowland and upland locations. This involved the tagging of 23,000 individual fish. Hybrid vigor (harvest weight advantage of crossbreeds over parents) was low (average 4.3%) and significant in only 22 crosses, of which only 7

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[24] Eknath, Ambekar, et al. 1993. Genetic Improvement of Farmed Tilapias: The Growth Performance of Eight Strains of *Oreochromis niloticus* Tested in Different Farm Environments. *Aquaculture* 111: 171–188.

performed better than the best pure strain. The best crossbreed had only an 11% harvest weight advantage over its parents.[25] Crossbreeding requires management of separate parental stocks—a more complicated system than selective breeding. Therefore, given the low hybrid vigor recorded from crosses, selective breeding was chosen as the breeding strategy for the development of GIFT.

GIFT tilapia collection in concrete tanks, Philippines

SELECTIVE BREEDING

Procedures. To ensure high genetic variability before selection, a synthetic base population was built from the 25 best-performing groups of the 64 tested. The development and characteristics of this synthetic base population have not yet been adequately described in a peer-reviewed journal, but this is to be remedied in 2005.[26] The synthetic base population was the genetic material used for selective breeding to develop GIFT. To select for weight at harvest, starting with the base population and continuing for successive generations, 200 tilapia families were established in

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[25] Bentsen, Hans, et al. 1998. Genetic Improvement of Farmed Tilapias: Growth Performance in a Complete Diallel Cross Experiment with Eight Strains of *Oreochromis niloticus*. *Aquaculture* 160: 145–173.

[26] According to the WorldFish Center, Penang, Malaysia, the forthcoming publication will be entitled Genetic Improvement of Farmed Tilapias: Composition and Genetic Parameters of a Synthetic Base Population of *Oreochromis niloticus* for Selective Breeding.

breeding *hapas* (small net cages) by mating 100 selected males with 200 selected females. Representative samples of their progeny were tagged, distributed to test environments and grown for 120 days. Breeders were selected for the next generation using standard quantitative genetics methods.

Catching tilapia breeders with a net

Responses to Selection. During the development of GIFT in the Philippines, responses to selection for improvement in weight at harvest (% gain over the previous generation) over five generations of selection were 19.1%, 13.5%, 9.2%, 17.8%, and 6.2%, respectively, totaling 65.8%.[27] These results have not yet been adequately published in peer-reviewed journals, and remain somewhat controversial. The main point at issue is the validity of control values used for comparisons between and across generations. AKVAFORSK and the WorldFish Center are currently reanalyzing the data from this work, and further publications concerning responses to selection are expected in 2005.[28] Critics have noted that the synthetic base

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[27] (i) Eknath, Ambekar. 1992. *Genetic Improvement of Farmed Tilapias. Final Report*. Manila: ICLARM;
(ii) Eknath, Ambekar, and Belen O. Acosta, eds. 1998. *Genetic Improvement of Farmed Tilapia Project Final Report (1988–1997)*. Manila: ICLARM.

[28] According to the WorldFish Center, Penang, Malaysia, the forthcoming publications will be entitled (i) Genetic Improvement of Farmed Tilapias: Genetic Parameters (for body weight at harvest) in *Oreochromis niloticus* During Five Generations and in Multiple Environments, and (ii) Genetic Improvement of Farmed Tilapias: Response during Five Generations of Selection (for increased harvest weight) in *Oreochromis niloticus*.

population itself, before any selective breeding, was reported to have a 60% advantage in harvest weight over widely farmed Philippine strains (footnote 27). This could be mostly attributed to the crossbreeding of strains during development of the synthetic base population. Together with the subsequent responses to selection, this represents a claimed growth performance advantage of about 125% for GIFT over Philippine farmed strains. In other words, in comparable environments, GIFT should reach harvest size in less than half the time taken by unimproved tilapia strains. However, subsequent comparisons (including those during DEGITA) of the performance of GIFT and other Nile tilapia farmed in Asia show much lower advantages for GIFT and, in some cases, show insignificant differences. This is because the results of any such comparison among strains are valid only for the environment (location, time, and farming system) where they are obtained. A wide range of differences in performance between GIFT and nonGIFT tilapia in Asia is to be expected, given the region's history of tilapia movements and variable attention to broodstock management, as well as local adaptation of farmed tilapia strains. Despite these complexities, the developers of GIFT demonstrated that selective breeding produced progressively faster growing generations of Nile tilapia, and that application of genetics to tilapia farming—and by inference to tropical aquaculture in general—can result in substantial and rapid development of improved Nile tilapia strains.

Tilapia breeding *hapas*

EVALUATION OF GENETICALLY IMPROVED FARMED TILAPIA

Regional Dissemination. As host for the development of GIFT, and having witnessed the superiority of GIFT in growth performance over the widely farmed Nile tilapia, the Philippines in 1993 was the first Asian country to adopt GIFT for use in a national tilapia breeding program, with dissemination and evaluation countrywide. During 1994–1997, GIFT were disseminated from the Philippines to four other national program partners in DEGITA (Bangladesh, PRC, Thailand, and Viet Nam) and to the Fiji Islands and Indonesia (Table 1).

Table 1: Regional Dissemination of Genetically Improved Farmed Tilapia, 1994–1997

Recipient	Month/Year Distributed	Number of Fingerlings
Bangladesh		
Fisheries Research Institute, Mymensingh	July 1994	1,000
Fisheries Research Institute, Mymensingh	August 1996	1,163
People's Republic of China		
Shanghai Fisheries University, Shanghai	June 1994	9,100
Fiji Islands		
MOA, Fisheries and Forestry, Suva	August 1997	800
Indonesia		
RIFF, Bogor	June 1994	4,000
RIFF, Sukamandi	August 1997	2,200
Thailand		
NAGRI, Bangkok	October 1994	2,000
Asian Institute of Technology, Bangkok	October 1994	1,000
NAGRI, Bangkok	January 1995	3,000
Asian Institute of Technology, Bangkok	January 1995	2,000
NAGRI, Bangkok	February 1996	8,000
Viet Nam		
RIA No. 1, Hanoi	May 1994	2,150
RIA No. 2, Ho Chi Minh City	January 1996	8,000
RIA No. 1, Hanoi	August 1996	750
Total		**45,163**

MOA = Ministry of Agriculture, NAGRI = National Aquaculture Genetic Research Institute, RIA = Research Institute for Aquaculture, RIFF = Research Institute for Freshwater Fisheries.

Source: Eknath, Ambekar, and Belen Acosta, eds. 1998. *Genetic Improvement of Farmed Tilapia Project Final Report (1988–1997).* Manila: ICLARM.

Protocols. All of the five national program partners in DEGITA used the same standard evaluation protocols that included baseline surveys and comparative trials with GIFT and locally farmed tilapia strains, on-station and on-farm.[29] These protocols were innovative in aquaculture research in their combination of ex-ante and ex-post assessments at both the household and country levels. Their unique feature was an ex-ante assessment of GIFT at the start of technology adoption, rather than its assessment ex-post, as is typical of aquaculture technology impact assessments and evaluations of adoption versus nonadoption. Ex-ante assessments during DEGITA provided researchers and developers with early feedback on users' needs, identified areas where further research was needed, and contributed to increased understanding of the dynamics between new technology, prevailing socioeconomic conditions, and agroecological environments. The baseline surveys conducted through DEGITA covered the history of tilapia introductions; regional distribution of tilapia farming and trends in production, yield, and methods; socioeconomic status of tilapia farmers; tilapia consumption, marketing, and trade; environmental impacts of tilapia and tilapia farming; government policies; and future developments. Throughout DEGITA, the five national program partners monitored water and soil quality at test sites, as well as water-use patterns and conflicts. The national partners also kept watch for any reports of adverse impacts from GIFT on aquatic biodiversity and the environment.

Comparative Evaluation of GIFT On-station. On-station trials during DEGITA were conducted in Bangladesh, PRC, Thailand, and Viet Nam to compare the performance of GIFT with available farmed strains of Nile tilapia. The Philippines was excluded because of the many on-station trials already conducted there during the development of GIFT. In ponds, GIFT gave better yields than local tilapia strains (ranging from 15% higher in Viet Nam to 65% higher in Bangladesh). In cages, GIFT gave 7% and 69% better yields than local tilapia strains, respectively, in the PRC and Bangladesh.[30] There were wide variations in tilapia farming expertise, practices, and production environments among and within countries, which precluded firm conclusions from on-station trials about any overall comparative advantage of GIFT.

Comparative Evaluation of GIFT On-farm. On-farm trials to compare the growth performance of GIFT with that of locally farmed

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[29] ICLARM. 1998. *Dissemination and Evaluation of Genetically Improved Farmed Tilapia Species in Asia: Final Report*. Manila.

[30] Source: WorldFish Center, Penang.

tilapia strains were conducted in diverse agroecological zones in all five DEGITA participating countries. The farming methods used included ponds and cages with different levels of inputs (fertilizers and feeds). Again, the results were very variable among and within countries. For example, in farm ponds in Viet Nam and Bangladesh, GIFT gave 33% and 78% higher yields, respectively, than those of local tilapia strains. In cage farming in the PRC and the Philippines, GIFT gave 25% and 54% higher yields, respectively, than those of local strains (footnote 29). The GIFT used for these on-farm trials were derived from only 2–4 generations of selection on the GIFT base population in the Philippines. They were being compared across the region with diverse farmed tilapia strains, all of which lacked a history of sustained genetic improvement but which were also very variable in quality. For example, the widely farmed Chitralada strain in Thailand had an excellent reputation and well-proven track record among farmers and researchers, compared with those of local tilapia in Bangladesh. Moreover, some local tilapia strains would have had some initial advantages over GIFT in terms of local adaptation. Despite these complications, the on-farm trials indicated that GIFT were sometimes significantly superior to, and in no cases significantly inferior to, the locally farmed tilapia strains with which they were compared. An analysis that accounted for heterogeneity of farm environments and practices showed some statistically significant higher average weights at harvest of GIFT and some higher survival of GIFT than those of locally farmed tilapia strains (Table 2).

Table 2: Examples of On-farm Trials in which GIFT Had Significantly Higher Average Harvest Weights and Survival than Locally Farmed Tilapia Strains

Country	Farm Type	Increased Harvest Weight (%)	Increased Survival (%)
Bangladesh	Pond	+57.9[a]	
People's Republic of China	Pond/Cage	+17.5[a]	+3.3[c]
Philippines	Pond	+34.2[b]	+13.9[b]
Thailand	Pond	+32.3[c]	
Viet Nam	Pond	+32.3[c]	

p = probability.

[a] significant, $p<0.01$; [b] significant, $p<0.05$; [c] significant, $p<0.10$.

Source: Modified from Dey, Madan, Ambekar Eknath, Li Sifa, Mohammad Hussain, Tran Mai Thien, Nguyen van Hao, Simeona Aypa, and Nuanmanee Pongthana. 2000. Performance and Nature of Genetically Improved Farmed Tilapia: A Bioeconomic Analysis. *Aquaculture Economics and Management* 4(1–2): 83–101. Original source: raw data from Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA).

KEY OUTCOMES AND RELATED ISSUES

NATIONAL TILAPIA BREEDING PROGRAMS AND RELATED RESEARCH

Relevance of GIFT. The development of GIFT has clearly demonstrated to participating national partners that rapid genetic improvement of farmed tilapia through selective breeding is possible. In Bangladesh, Fiji Islands, Philippines, Thailand, and Viet Nam, national tilapia breeding programs and related tilapia genetics research are now based mainly or exclusively on GIFT or GIFT-derived strains using approaches based on selective breeding. GIFT are also used extensively in research for development of tilapia farming in PRC, Indonesia, and Malaysia. As DEGITA demonstrated, the magnitude of the advantages of GIFT over other Nile tilapia strains has varied, depending on many genetic and environmental factors and on their interactions. The dissemination of GIFT through DEGITA and INGA was the first provision of genetically improved tilapia to researchers, breeders, seed producers, and farmers in many countries in the Asia and Pacific and other regions.

GIFT have generally performed as well or better, and in some countries much better, than existing farmed tilapia. GIFT and GIFT-derived strains have proven to be good genetic material for continued selective breeding. Recent research has confirmed the genetic variability of GIFT, which is a good basis for selection.[31]

GIFT have also been compared with other tilapia strains for performance traits that were not included in GIFT development, but which have current or future importance for tilapia seed producers and growers. These comparisons highlighted unforeseen performance traits of GIFT. For example, researchers found that the average percentage fillet yield from GIFT (38.0%) is higher than that of the Chitralada Nile tilapia (34.4%), which was formerly the strain most

[31] (i) Romana-Eguia, Maria Rowena, Minoru Ikeda, Zubaida Basiao, and Nobuhiku Taniguchi. 2004. Genetic Diversity in Farmed Asian Nile and Red Tilapia Stocks Evaluated from Microsatellite and Mitochondrial DNA Analysis. *Aquaculture* 236: 131–150.
(ii) Rutten, Marc, Hans Komen, R. Deerenberg, M. Siwek, and Henk Bovenhuis. 2004. Genetic Characterization of Four Strains of Nile Tilapia (*Oreochromis niloticus* L.) using Microsatellite Markers. *Animal Genetics* 35: 93–97.

widely farmed in Thailand.[32] Other studies show comparative advantages for GIFT in reproductive traits, such as egg size and hatching success. In fish farming, comparatively large eggs are usually positively correlated with high hatching success and good early growth and survival, although large egg size often means lower number of eggs per female. Recent results, for which publications are pending, indicate an average GIFT egg diameter of 3.2 millimeters compared with 3.0 millimeters for the Chitralada strain, with hatching percentages of 68% for GIFT and 41% for Chitralada. The corresponding fecundities (number of eggs produced per gram of body weight per female) were 96.9 for GIFT and 127.5 for Chitralada.[33] In tilapia farming, as in trout farming, the advantages of large egg size will probably become more important than high fecundity and could result in higher prices for the fast-growing and robust tilapia seed that are typical of large eggs with high hatching success.

GIFT-related Methods. GIFT-related methods are used, wholly or partly, in all the national tilapia breeding programs based on GIFT and GIFT-derived strains and related research. During the development of GIFT and through DEGITA, there were substantial transfers of GIFT-related methods, with training for their application in R&D. Publication of GIFT-related methods followed,[34] supplemented by a manual.[35] Eleven graduate students completed their Master of Science degrees through involvement in the development of GIFT. Training in GIFT-related methods and approaches has been extended to relevant national institutes of the nine Asia and Pacific and five African member countries of INGA. The relevance and applicability of GIFT-related methods have been demonstrated by the use of these methods for genetic improvement of other farmed fish: for example, silver barb *(Barbodes gonionotus*) in Bangladesh and Viet Nam, rohu (*Labeo rohita*) in Bangladesh and

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[32] (i) Rutten, Marc, Henk Bovenhuis, and Hans Komen. 2002. Modeling Fillet Weight in Nile Tilapia. Abstract No. 06–13 of Paper presented at the World Congress on Genetics Applied to Livestock Production, 19–23 August, Montpelier, France.
(ii) Rutten, Marc, Henk Bovenhuis, and Hans Komen. 2004. Modeling Fillet Traits based on Body Measurements in Three Nile Tilapia Strains (*Oreochromis niloticus* L.). *Aquaculture* 231(1–4): 113–122.

[33] Personal communication: Hans Komen, Wageningen Agricultural University, Netherlands.

[34] Acosta, Belen, and Ambekar Eknath. 1998. *Manual on Genetic Improvement of Farmed Tilapia (GIFT) Research Methodologies*. Manila: ICLARM.

[35] WorldFish Center. 2004. *GIFT Technology Manual: An Aid to Tilapia Selective Breeding*. Penang.

India, mrigal (*Cirrhinus mrigala*) in Viet Nam, and blunt snout bream (*Megalobrama amblycephala*) in the PRC.[36]

Tilapia Gene Banking. Large collections of crop varieties and carefully maintained livestock breeding nuclei and cryopreserved sperm and embryos, commonly called gene banks, are the basis of most of the world's plant and livestock breeding and related research. By comparison, fish gene banks are rare and inadequately supported, especially in tropical developing countries.[37] The Nile tilapia broodstock assembled for the development of GIFT, together with the GIFT synthetic base population and subsequent generations of selectively bred GIFT, comprise one of the world's most valuable tilapia gene banks, housed in the Philippines at NFFTC. The descendants of these fish remain available from this gene bank for national, regional, and international research and breeding purposes. Until 1999, the national tilapia breeding program of the Philippines was based entirely on successive generations of selectively bred GIFT. Subsequently, NFFTC conducted further R&D and chose to develop a new synthetic base population by crossbreeding the latest GIFT generation with a nonGIFT strain bred at FAC (called FAST) and with the original Egypt and Kenya wild strains collected for the development of GIFT.[38] This would not have been possible without further costly introductions from Africa if these wild Nile tilapia strains had not been available from the gene bank. The result was a GIFT-derived strain, which NFFTC calls GET EXCEL strain and which is now the basis of the Philippine national tilapia breeding program, under continuing selection using GIFT methods.

During the development of GIFT, a gene bank of cryopreserved sperm was established at NFFTC through assistance from the Institute of Aquaculture, University of Stirling, UK. This complements the gene bank's collection of live broodstock. In 2003, the Philippine Government upgraded this gene bank facility with provision of a new building. In 1995, an external review of ICLARM recommended, for security purposes, duplication of the GIFT and cryopreserved sperm

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[36] Gupta, Modadugu, and Belen Acosta, eds. 2001. Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics in Aquaculture. *ICLARM Conference Proceedings* 64. Manila.

[37] Harvey, Brian, Carmen Ross, David Greer, and Joachim Carolsfeld, eds. 1998. Action before Extinction: An International Conference on Conservation of Fish Biodiversity. Victoria, B.C.: World Fisheries Trust.

[38] Tayamen, Melchor. 2004. Nationwide Dissemination of GET EXCEL Tilapia in the Philippines. Paper presented at the Sixth International Symposium on Tilapia in Aquaculture, 12–16 September 2004, Philippine International Convention Center, Manila, Philippines.

gene banks at other sites.[39] This has not yet been adequately achieved, apart from some duplication of the live fish collection at facilities of the Freshwater Fisheries Research Center, Jitra, Malaysia, in partnership with the WorldFish Center. In common with most other cryopreserved fish sperm gene banks around the world, the NFFTC collection of tilapia sperm has not yet been adequately used or tested for viability. However, it is invaluable as a long-term resource for obtaining genetic material from the history of development of GIFT. The WorldFish Center plans further work to determine more precisely the magnitude of genetic gains achieved during the development of GIFT, by breeding trials using cryopreserved sperm from the GIFT founder stocks, the GIFT base population, and successive generations of selectively bred GIFT.[40]

Tilapia gene bank at NFFTC, Philippines

[39] This was part of an external review of all gene banks operated by or in partnership with the 16 international agricultural research centers of the Consultative Group on International Agricultural Research (CGIAR).

[40] Personal communication: Raul Ponzoni, WorldFish Center.

Aquaculture Genetics Research. Without the ADB TA (footnote 17) and related funding from UNDP and others, aquaculture genetics research in general and tilapia genetic improvement research in particular would probably have been delayed by at least 10 years in the Asia and Pacific region. Without such funding, the capacities of the research institutes that participated in the development and dissemination of GIFT and became members of INGA would have had fewer facilities and weaker staff, and would not have been eligible for further support from funding agencies for application of genetics in aquaculture. Without the TA for the development of GIFT and for DEGITA, neither INGA nor GFII would have been established. Moreover, tilapia researchers in Bangladesh, PRC, Fiji Islands, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam would have continued to use Nile tilapia strains that were mostly inferior to GIFT, especially in terms of their genetic variability. In addition, GIFT would not have been available in many other countries, including India, Lao People's Democratic Republic (Lao PDR), Nepal, Netherlands, UK, and US. Parallel to the growth of tilapia farming and subsequent to the development of GIFT, tilapia genetics has become an immense research field, comprising population and conservation genetics; quantitative genetics for genetic improvement; and molecular genetics, including mapping of the tilapia genome.[41] GIFT, GIFT-related methods, their adoption in tilapia breeding programs, and INGA are ongoing contributors to this expansion of tilapia genetics research and the application of its results in the responsible development of tilapia farming.

The development and dissemination of GIFT have proven to be meaningful investments with attractive economic returns. The WorldFish Center estimated that the economic internal rate of return on investments in GIFT development and dissemination was more than 70% over a period from 1988 to 2010, with adoption of GIFT commencing in 1996.[42] For this estimate, the WorldFish Center quantified the costs and benefits of the development and dissemination of GIFT in six countries (Bangladesh, PRC, Indonesia, Philippines, Thailand and Vietnam) where farmers have used the GIFT and GIFT-derived strains, taking into account yield gains, cost reductions at the farm level, the elasticity of demand for and the

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[41] Penman, David, and Brendan McAndrew. 2000. Genetics for the management and improvement of cultured tilapias. In *Tilapias: Biology and Exploitation*. Edited by Malcolm Beveridge and Brendan McAndrew. Dordrecht: Kluwer Academic Publishers. p. 227–266.

[42] Deb, Uttam, and Madan Dey. 2004. *The History and Impacts of the Genetic Improvement of Farmed Tilapia and the Dissemination and Evaluation of Genetically Improved Tilapia*. Penang: WorldFish Center.

elasticity of supply of tilapia in these countries.[43] The net present value of the costs and benefits of the development and dissemination of GIFT was estimated at $368 million in constant 2001 prices with an annual discount rate of 7%.

Collecting tilapia sperm for cryopreservation

INSTITUTIONAL EFFECTS

Networks and Channels of Dissemination. Multinational and multilevel networks accelerated the dissemination of GIFT, GIFT methods, and information on improved tilapia farming practices. These networks have been complemented by diverse dissemination channels that have helped strengthen the linkage between genetics research and distribution of improved tilapia breeds to farmers. Dissemination under DEGITA (1994–1997) was in collaboration with national aquaculture research institutes in five Asian countries that had interest in distributing GIFT and had facilities for fish breeding. Linkages between these national research institutes and a network of

[43] A price elasticity of demand for tilapia of –1.00 was assumed for Bangladesh, Indonesia, Philippines and Thailand; –0.80 for PRC; and –1.40 for Viet Nam. A price elasticity of supply of 0.50 was assumed for PRC, Indonesia, Philippines, Thailand and Vietnam; and 0.40 for Bangladesh.

private and public hatcheries, in turn, provided farmers with access to GIFT. In some cases (Philippines and Thailand), preexisting alliances between research institutes and a broad-based hatchery network facilitated GIFT dissemination.

In addition to research institutes and hatcheries, fish seed traders served as dissemination channels for GIFT and helped link tilapia seed producers to customers. This was evident in Thailand, and to some extent, in Viet Nam, where good infrastructure allowed quick transport of tilapia seed by traders to farms. Well-functioning markets and distribution networks helped meet the requirements of fish farmers in the Philippines as well. Farmer-to-farmer contacts and social networks among members of rural communities hastened the spread of GIFT and of tilapia farming practices. Tilapia hatcheries have also emerged as providers of technical information and advice, complementing the traditional extension role of government.

At the international level, the establishment in 1993 of INGA helped the dissemination of GIFT, GIFT methods, and information on a broader front (Appendix 1). INGA has provided international linkages, initially through DEGITA, which was considered by its national program partners as the first regional collaborative effort associated with INGA, and thereafter through members sharing their R&D experience and tilapia germplasm.[44] INGA's diverse interregional membership[45] and its assistance to member countries in sharing GIFT for research, use in national tilapia breeding programs, and distribution to farmers helped heighten interest in GIFT and expanded opportunities for dissemination to many countries. Transfers of GIFT and other tilapia germplasm[46] have involved

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[44] Gupta, Modadugu, and Belen Acosta. 2001. Networking in Aquaculture Genetics Research. In Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics Research in Aquaculture, edited by Modadugu Gupta and Belen Acosta. *ICLARM Conference Proceedings*. 64. p. 1–5. Manila.

[45] WorldFish Center. 2003. *International Network on Genetics in Aquaculture: Final Report (July 2001 to December 2003)*. Report submitted to the Norwegian Agency for Development Cooperation. Penang: WorldFish Center. INGA was established with 11 founding developing member countries (Bangladesh, People's Republic of China, Côte d'Ivoire, Egypt, Ghana, India, Indonesia, Malawi, Philippines, Thailand, and Viet Nam) and with ICLARM (now the WorldFish Center) as member-coordinator. The Fiji Islands and Malaysia joined INGA in 1996. INGA also has 12 advanced scientific institutional members in Asia, Australia, Europe, Israel, and the US. Three associate members were admitted to INGA in August 2003: GFII; Asian Institute of Technology, Thailand; and University of Western Australia.

[46] During 1994–2003, INGA transferred 133,494 tilapia as germplasm for research and breeding programs, comprising GIFT strain (70,913) and other tilapia species and strains (62,581), including blue tilapia and other Nile tilapia strains. Source: WorldFish Center 2003 (footnote 45).

Bangladesh, PRC, Côte d'Ivoire, Egypt, Fiji Islands, India, Indonesia, Kenya, Lao PDR, Malaysia, Papua New Guinea, Thailand, and Viet Nam. All such transfers were made under the voluntary INGA protocols for biosafety, including quarantine, that were derived from procedures adopted during the development of GIFT (footnote 27).

Another enabling agent for GIFT dissemination is GFII, which was incorporated in the Philippines in 1997 as a nonstock, nonprofit, independent foundation to distribute GIFT on a commercial scale and to continue selective breeding efforts with GIFT (Appendix 1). GFII was established as an offshoot of the TA that funded the development of GIFT. GFII entered into partnerships with seven private tilapia hatcheries in the Philippines through formal licensing arrangements.[47] By the end of 2001, it had disseminated 522,700 GIFT broodstock to these GIFT-accredited private hatcheries. Despite its partnership with private tilapia hatcheries, GFII could not sustain its operations financially on its own, and was forced to look for alternative commercial partnerships by capitalizing on its human resources, R&D capability, and existing GIFT-related assets.

In 1999, GFII drew up an agreement with Genomar ASA (formerly Biosoft ASA) of Norway, under which GFII and Genomar ASA agreed to pursue collaborative research for further genetic improvement of GIFT in the Philippines, allowing exclusive rights to Genomar ASA for commercialization of the resulting new GIFT generations. Under this agreement, GFII contributed tilapia breeding stocks and other assets to Genomar ASA in exchange for an equity position in Genomar ASA. This commercial alliance was aimed at intensifying commercialization and dissemination of high-performance tilapia seed to fish farmers to meet the demand for food fish of a growing population. GFII also retained its own historical GIFT broodstock to continue independent R&D. New GIFT generations bred by GFII and commercialized by Genomar ASA have been produced in Genomar-accredited hatcheries in the Philippines and sold as Genomar Supreme Tilapia, a registered trademark.[48] Genomar's operations in production and marketing of GIFT-based fish seed have also expanded to Bangladesh, the PRC, and Thailand.

Despite rapid transfers of GIFT to many countries, institutional, market, and technical factors have constrained GIFT production and

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[47] Acosta, Belen, and Modadugu Gupta. 2004. Public-Private Partnerships for Tilapia Genetics Research in the Philippines: Case Study on GIFT and Lessons Learned. Paper presented at the Workshop on Public-Private Partnerships in Tilapia Genetics and Dissemination of Research Outputs, 21–23 January 2004, Tagaytay City, Philippines. CD-ROM.

[48] http://www.genomar.no/section.cfm

dissemination in Bangladesh, where tilapia farming has not yet contributed much to freshwater aquaculture production. These constraints include (i) continuing emphasis on carp polyculture, which has traditionally dominated inland aquaculture in the country; (ii) limited government resources to promote tilapia farming, including extension services; (iii) unreliable supply of good-quality tilapia seed; and (iv) lack of access by hatchery operators and fish farmers to various services to support tilapia farming.

Public-Private Partnerships. The development and dissemination of GIFT have facilitated the expansion of public-private partnerships in varying degrees. Key areas of collaboration that have emerged include seed production, seed distribution, extension, financing for farm operations, and setting directions for the tilapia sector. In the Philippines, for example, public-private partnerships have progressed beyond tilapia production and distribution to engaging stakeholders in joint planning for the tilapia sector. To assure a reliable supply of tilapia seed to growout farmers, both the Government and the private sector have been active in improving tilapia broodstock quality and in maintaining linkages with a network of hatcheries in tilapia-producing regions. The longest standing partnerships are those between NFFTC of BFAR, its regional and provincial stations, and their hatchery operators and farmer clients. The continued presence of BFAR-operated tilapia hatcheries, however, in areas where private operators dominate, has been debated among observers and stakeholders because of possible conflicts with business interests of the private sector (footnote 47). There is now a call for a clearer delineation of roles between the Government and the private sector in tilapia seed distribution.

Private hatcheries and other input suppliers in the Philippines have complemented government efforts to promote tilapia production by advising tilapia farmers on appropriate farming practices, supplying tilapia seed, feeds, and fertilizers, and extending credit to tilapia farmers. In Lake Taal, Philippines, private financiers have entered into risk-sharing arrangements with cage farmers (footnote 15). The past two years saw new collaborative arrangements, mainly the establishment of the Tilapia Science Center[49] and of an industry association known as Philippine Tilapia, Inc, which have provided strategic venues for the Government and the private sector for charting the future of the tilapia sector, for exchanging information among tilapia stakeholders, and for hosting

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[49] FAC, the College of Fisheries of CLSU, NFFTC, GFII, and Phil-Fishgen have participated in the establishment and operations of the Tilapia Science Center located in Nueva Ecija, Philippines.

trade fairs and tilapia conventions to promote tilapia production. The developers of GIFT, GIFT-derived and other farmed tilapia and their public and private sector users have also forged joint agreements, for example, to work more closely together on conserving biodiversity and toward establishment of a fish seed certification system. Because of their importance as examples for wider application in aquaculture, these partnerships have become the subjects of intensive research, supported by IDRC and implemented by the WorldFish Center in collaboration with FAC, GFII, and NFFTC.[50]

In Thailand, the Government has performed a key role in tilapia breeding research and in maintaining good quality broodstock, primarily through the Aquatic Animal Genetics Research and Development Institute. Public access to GIFT in Thailand has been made possible through regional genetics centers, which distribute fish to become broodstock at private and public hatcheries, as well as through linkages with the inland fishery stations of the Department of Fisheries, which distribute tilapia seed and provide technical advice to farmers. A well-established network of local and distant seed traders links producers to customers all over Thailand. Similarly, in Viet Nam, the Research Institute for Aquaculture No. I, which is the lead government institute in fish breeding research and broodstock quality maintenance, has maintained public-private sector collaboration through national broodstock centers, which distribute tilapia broodstock to provincial centers, which, in turn, multiply broodstock for further distribution to private hatcheries and fish farmers. In Bangladesh, some partnerships in tilapia seed production and distribution have existed between the government-operated Bangladesh Fisheries Research Institute and several private hatcheries, as well as among private entrepreneurs. However, such partnerships are still nascent and limited in their technical and commercial cooperation. Importation of GIFT into Bangladesh from Thailand has recently generated further commercial interest among private tilapia hatcheries.

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[50] (i) Angeles Declaration. 2003. *Public-Private Partnerships for Dissemination of Research Outputs to End-users*. Angeles City, Philippines, 27 July 2003. Penang: WorldFish Center.

(ii) WorldFish Center. 2004. *Proceedings of the Final Workshop on Public-Private Partnerships in Tilapia Genetics and Dissemination of Research Outputs: Philippine Experience*. 21–23 January 2004, Tagaytay City, Philippines. Penang: WorldFish Center. CD-ROM.

IMPACTS OF GIFT OPERATIONS

POLICIES AND PLANS FOR EXPANSION OF TILAPIA FARMING

The development and dissemination of GIFT and GIFT-related methods have contributed substantially to raising public investment in the application of genetics to aquaculture in general and to tilapia farming in particular in the Asia and Pacific region. There is abundant evidence for this in the emergence of national tilapia breeding programs and associated staff and facilities development. Expansion of freshwater aquaculture in general and tilapia farming in particular has become one of the main pillars for increasing national fish supply in Bangladesh, Philippines, Thailand, and Viet Nam (footnote 15). Related policy and planning documents give high importance to fish genetic improvement and breeding programs. This is a substantial change from the situation in the 1970s and 1980s, when such documents typically cited only needs for increased quantities of seed supply, irrespective of breeding history and genetic determinants of performance.

National plans for tilapia, developed subsequent to the dissemination and use of GIFT, call for substantial increases in farmed tilapia production. For example, in the Philippines volumes are forecast to increase from 122,000 t in 2002 to 250,000 t in 2010, and in Viet Nam from 30,000 t in 2003 to 200,000 t in 2010.[51] Such plans for substantial increases in domestic production have considered both expanding domestic demand for tilapia and modest potential exports to Europe and the US. In Thailand, the current National Fisheries Policy calls for increasing farmed fish production by 5% annually, and it considers freshwater aquaculture as contributing mainly to increasing domestic fish consumption, especially to benefit the poor, with tilapia as a priority species.[52]

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[51] (i) Rodriguez, Basilio Jr. 2003. Updated Framework for the Tilapia Master Plan. 2003. Paper presented at the 2nd Tilapia Congress, 13–14 November 2003, San Fernando, Pampanga, Philippines.
(ii) Ministry of Fisheries. 2002. *Development of Tilapia Culture in the Period 2003–2010*. Hanoi.

[52] Department of Fisheries, Bangkok.

The feasibility of tilapia exports has not been thoroughly studied in the Philippines and Viet Nam. Increased productivity and reduced production costs alone are not sufficient for tilapia producers to tap export markets. The types and range of products, packaging, promotional efforts, pricing, and distribution channels are key factors to consider in accessing tilapia export markets. Tilapia products are imported into the US primarily as frozen whole, frozen fillets, and fresh fillets, with fresh and frozen fillets sold mostly through wholesalers and distributors to retail grocers and restaurants. Export markets virtually exclude live tilapia from being sold directly as food. Postharvest processing and value addition for tilapia food products are necessary to meet export demands. This is beyond any individual farmer's capacity.[53] Thus, entrepreneurial development beyond the farm is essential. For exports, the role of fish processing industries and market intermediaries is critical.

Cage farming in a reservoir, Thailand

[53] Marketable tilapia products include fresh whole and gutted, fresh boneless fillets, skin on or skinless, frozen whole and gutted, individualized quick frozen fillets, deep-skinned fillets, dried dressed, and smoke dressed. Further value additions may encompass a range of products, including breaded fillets, nuggets, and marinated fillets.

SOCIOECONOMIC IMPACTS

Impacts on Production of Farmed Tilapia. The substantial impacts of GIFT and GIFT-derived strains on farmed tilapia production are evident from their wide and increasing shares in tilapia seed supply. In the Philippines, the hatchery survey conducted for this study indicated that GIFT and GIFT-derived strains accounted for 68% of the total tilapia seed produced in 2003. In Thailand, the survey commissioned under this study found that GIFT contributed 46% of all national tilapia seed production. The market share of GIFT in Thailand can increase further if contracted tilapia growers (who currently use a commercial tilapia strain supplied exclusively from a large corporation) are permitted to acquire their own choice of tilapia seed.[54] The use of GIFT and GIFT-derived strains in the Philippines and Thailand is most likely to be sustained, having emerged as the most popular choices of hatchery respondents in these countries for their planned seed production in the next 5 years. In Viet Nam, sex-reversed GIFT seed contributed an estimated 17% to national production of farmed tilapia in 2003, and the overall contribution of GIFT and GIFT-derived strains to the national supply of Nile tilapia seed is expected to increase substantially because of the GIFT-based national tilapia breeding program. In Bangladesh, GIFT have yet to make a significant contribution to national freshwater aquaculture production, but this is likely to change, because the availability and popularity of farmed tilapia are increasing.

GET EXCEL, a GIFT-derived strain

[54] Excluding this tilapia seed supply to contracted farmers, the market share of GIFT seed in the remaining total supply of tilapia seed was 75% in 2003.

Newly harvested GIFT strain, Thailand

In the PRC, GIFT have seen extensive use in research to improve the growth and other performance traits of farmed tilapia. GIFT was found to have higher growth rates but lower cold tolerance than other Nile tilapia strains farmed there.[55] The PRC is the world's leading producer of farmed tilapia, with production estimated at more than 700,000 t in 2002. The diverse tilapia farming environments of the PRC, most of which require cold tolerance and some salinity tolerance, require breeding diverse tilapia strains and hybrids, to which GIFT are contributing.[56] In Hainan, GIFT are being commercialized through a joint venture, with plans for expansion to other parts of the PRC.[57] Since June 2002, some 30 million GIFT seed have been sold in Guangdong and Hainan provinces.[58] However, it remains to be seen to what extent GIFT and GIFT-derived strains will

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[55] Shanghai University of Fisheries, Shanghai, PRC.

[56] See http://www.fecc.agri.gov.cn/zsyz/7yy/5.htm

[57] This joint venture was established in 2002 between Genomar ASA, Norway and the Royal Supreme Seafood hatchery in Wenchang, Hainan, PRC. Available: http://www.royalsupreme.com/aquaculture.asp

[58] Lai, Qiuming, and Yang Yi. 2004. Tilapia Culture in Mainland China. Paper presented at the Sixth International Symposium on Tilapia in Aquaculture, 12–16 September 2004. Philippine International Convention Center, Manila, Philippines.

be further distributed and farmed in the PRC, either as Nile tilapia or as Nile tilapia male parents in the blue tilapia (*O. aureus*) x Nile tilapia hybrids that make up the bulk of PRC farmed tilapia production. The blue tilapia female parent in this hybrid cross contributes cold tolerance capabilities, and the cross also generates high percentages of male offspring.

Farming GIFT in ponds, Thailand

Impacts on Incomes of Tilapia Hatchery Operators and Farmers. Tilapia farming provides an attractive livelihood for hatchery operators and growout farmers. The hatchery surveys conducted for this study in the Philippines and Thailand indicated that hatchery operations were profitable. In the Philippines, GIFT and GIFT-derived hatchery respondents earned attractive returns during 2001–2003, but experienced stiff competition and rising seed production costs. Optimism among respondents about their future operations was found to increase with hatchery size. This confirms the relevance and significance of economy of scale in tilapia seed production. In Thailand, GIFT hatchery respondents had stable profits during 2001–2003, largely due to a continuing demand for GIFT and sustained marketing efforts. They were optimistic about improved profitability over the next 5 years due to a growing preference for high-quality seed of known provenance.

Indicative net returns[59] for tilapia hatcheries and farms in the Philippines and Thailand are shown in Table 3. For GIFT hatcheries,

[59] Net returns are defined as total revenues from sales of tilapia less total production costs and marketing expenses. Production costs include both cash costs and noncash costs, where noncash costs refer to depreciation and imputed family labor.

net returns are about $5,000/hectare (ha)/year. For GIFT growout ponds, excluding fish consumed by households on the farms, net returns range widely, from $1,783 to $4,241/ha/crop cycle, due to variations in the duration of the crop cycle, production costs, and farm gate prices of tilapia. Crop cycles differ according to the desired fish size at harvest: 8 months for relatively large fish (500–1,000 g/fish) and 4 months for smaller fish (up to about 250 g/fish). In the Philippines, 4-month crop cycles, allowing two crops a year to fit climatic and seasonal conditions, are common. In some parts of central and northern Thailand, tilapia farmers have 8-month crop cycles once a year and 6-month crop cycles twice a year.

Table 3: Indicative Net Returns from Farming GIFT in 2003

Farm Type and Unit of Measure	Philippines		Thailand	
	P	$[a]	B	$[b]
Hatchery (per ha/year)	275,000	5,074	200,000	4,819
Growout pond (per ha/crop)				
4-month crop cycle	101,188	1,867		
6–6.5 month crop cycle			74,000–137,000	1,783–3,301
8-month crop cycle			176,000	4,241
Growout cage (per cage/crop)[c]				
Cage size 10x10x10 m (5–6 month crop cycle)	21,119	390		
Cage size 3x6x2.5 m (4-month crop cycle)			4,285	103

ha = hectare, m = meter.

[a] $1=P54.2.

[b] $1=B41.5.

[c] Cage sizes and stocking rates vary, and total household incomes depend on the number of cages operated.

Sources: Key informant interviews and surveys.

For GIFT in growout cages, indicative net returns are from $103 to $390/cage/cycle, depending on the cage size and crop cycle duration, among other factors. At Lake Taal, Philippines, a fish farmer with four cages who harvests tilapia twice a year can earn net returns of $3,120 a year (footnote 15).[60] In northern Thailand, a farmer who farms GIFT in cages along the Ping River as a secondary income source has earned net returns of $1,236 a year (four cages, three crop

[60] The rural poverty line in the Philippines in 2000 was at P73,392 ($1,660) per year per family of six members. Source: ADB Database, Poverty and Development Indicators.

cycles a year).[61] In Bangladesh and Viet Nam, returns from pond and cage farming are not sufficiently documented. However, some evidence from fishpond trials in northwest Bangladesh indicates that the average net income from fish polyculture (excluding own consumption of fish households) is about Tk50,470/ha ($967) for an 8–month crop cycle.[62] Here, GIFT comprise 20% of fish production, but are largely meant for household consumption among small-scale and poor fish farmers.[63]

Impacts on Employment. Dissemination and adoption of GIFT and GIFT-derived strains have contributed significantly to the expansion of employment in tilapia farming. At least 280,000 people in the Philippines (footnote 15) and 200,000 people in Thailand, inclusive of their families, directly and indirectly benefit annually from employment generated by tilapia farming alone. The poor and small-scale farmers are among those who benefit from employment in tilapia farming and its associated activities. These estimates do not include additional full-time, part-time, and seasonal labor required by tilapia farms and by allied industries, such as tilapia feed processing, fertilizer and other suppliers, and their respective distribution, for which data are difficult to obtain. Based on the hatchery surveys conducted for this study, GIFT and GIFT-derived hatcheries in the Philippines and Thailand generated employment for about 68% and 45%, respectively, of their national tilapia hatchery workforces in 2003. Employment from farming GIFT was not sufficiently documented in Bangladesh and Viet Nam. Although the impact of GIFT on employment in Bangladesh is to date limited, the potential for growth in employment due to GIFT and tilapia farming is promising.[64]

Impacts on Human Nutrition. Tilapia contribute to the nutrition of fish consumers, including the poor, because it is a relatively low-priced fish. In tilapia farming regions of the Philippines, rural producers had much higher annual tilapia consumption (39.5 kilogram [kg]/person) than rural nonproducers (15.9 kg/person) and

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[61] The rural poverty line in Thailand in 2000 was at B39,600 ($987) per year per family of four members. Source: ADB Database, Poverty and Development Indicators.

[62] The rural poverty line in Bangladesh in 2000 was at B38,880 ($745) per year per family of five members. Source: ADB Database, Poverty and Development Indicators.

[63] Barman, Benoy. 2000. Assessment of Nile Tilapia (*Oreochromis niloticus*) Seed Production and Growout Systems for Small-Scale Farmers in Northwest Bangladesh. Doctoral dissertation. Bangkok: Asian Institute of Technology. 251 p.

[64] With as much as 400,000 ha under fish farming in Bangladesh, direct, full-time employment may reach more than 800,000 people, assuming a minimum requirement of 2 persons/ha. Most of the work is part time, however, and the number of people directly involved in fish farming is probably much more than 2 million (footnote 15).

urban nonproducers (5.8 kg/person).[65] Home consumption among household producers is common in the Philippines. Tilapia has been a more affordable source of protein than pork and chicken (Appendix 2, Figure A2.2). A marine fish, the round scad (*Decapterus* spp., locally called *galunggong*) has traditionally been the fish most available to and affordable by poor Philippine consumers. Recently, retail prices of tilapia have fallen below those of round scad. In the Philippines, recent estimates indicate that tilapia has a demand elasticity that ranges from 1.24 for the lowest income group to 0.99 for high-income groups. This implies that lower income groups tend to respond more to price changes.[66] For example, a 10% decrease in tilapia prices will increase tilapia consumption by lower income groups by 12.4%. Thus, the poor stand to benefit from lower tilapia prices.

Gathering GIFT fingerlings in Viet Nam

[65] Dey, Madan, Mohammad Rab, Ferdinand Paraguas, Somying Piumsombun, Ramachandra Bhatta, Mohammad Ferdous Alam, and Mahfuzuddin Ahmed. 2004. Fish Consumption in Selected Asian Countries. Paper presented at the Final Workshop on the Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia, held at the Asian Development Bank, 17–20 March 2004, Manila, Philippines.

[66] *Analysis of Fish Demand in the Philippines*. Study conducted by Dr. Yolanda Garcia, Dr. Madan Dey, and Ms. Sheryl Narvaez as part of the Philippine Component of Asian Development Bank TA 5945-REG *Study on Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia*, for $1.1 million, approved on 17 October 2000.

Across various regions of Thailand, tilapia was the single most preferred freshwater species. Surveys of fish consumers in selected inland areas of Thailand (1998–1999) showed annual tilapia consumption of 31.6 kg/person by rural producers; 30.5 kg/person by rural nonproducers; and 23.5 kg/person by urban nonproducers (footnote 65). The main reasons for preferring tilapia were good taste, availability, easy preparation, and reasonable price. Tilapia is a relatively low-priced fish in Thailand, and more than 90% is marketed domestically, providing a widely available and affordable fish for poor consumers in rural and urban areas. The poorest income group in Thailand spent more of its fish expenditures on tilapia than did the highest income group (25% versus 13%) in 1998–1999. Tilapia was a more affordable source of protein for the poor at a retail price of $0.69/kg on average, compared with snakehead (*Channa striata*, $1.70/kg) and chicken ($1.52/kg). The widening use of GIFT indicates the current and potential future contributions of tilapia to human nutrition in Thailand.

In Viet Nam, available information suggests that tilapia were more affordable than other widely available freshwater fish (snakehead and common carp) but accounted for not more than 10% of the total fish expenditures in some locations in northern Viet Nam, and 2% in southern Viet Nam. Tilapia are currently still in limited supply, and consumers are not yet fully familiar with the fish. The rising popularity and expansion of tilapia farming, increasing awareness, and growing acceptance of tilapia among consumers will expand the domestic market, with wider availability of GIFT contributing significantly.

In Bangladesh, average annual tilapia consumption (1998–1999) in selected inland areas was about 2.5 kg/person (footnote 65), but the average per capita consumption across the country was not available. The role of farmed tilapia in meeting poor people's needs and its demand in formal markets are becoming more apparent.[67] For example, there was a misconception that tilapia were unimportant in northwestern Bangladesh because few tilapia were seen in markets.[68] Many small-scale farmers were found to stock tilapia in polyculture with carps in small ditches and borrow pits near the households. Among poorer households, tilapia are mostly consumed by the households.

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[67] Barman, Benoy K., David C. Little, and Johannes Janssen. 2003. Tilapia Culture Systems in Bangladesh. *Global Aquaculture Advocate* 6(4): 31–33.

[68] Barman, Benoy K., David C. Little, and Peter Edwards. 2002. Small-Scale Fish Culture in Northwest Bangladesh: A Participatory Appraisal Focusing on the Role of Tilapia. In *Rural Aquaculture*, edited by Peter Edwards, David C. Little, and Harvey Demaine. Wallingford, UK: CABI Publishing. p. 227–244.

As GIFT and GIFT-derived strains have significantly increased the supply of farmed tilapia, this should have a favorable impact on affordable fish supply to the rural and urban poor in countries where tilapia are farmed.

IMPACTS ON THE ENVIRONMENT AND BIODIVERSITY

The development and dissemination of GIFT inevitably raised questions as to whether they, and any modifications that they might initiate in farming methods, could cause adverse impacts on the natural environment and on biodiversity. Great efforts were made prior to and during the TA to assess and to avoid such possible adverse impacts. Researchers and developers of GIFT recognized that fish introductions and transfers, and indeed success in fish genetic improvement, require appraisal of environmental impacts. An international workshop on these concerns was convened as part of the TA (footnote 17[i]), and detailed recommendations were made to ICLARM and its research partners with respect to the development and dissemination of GIFT.[69] The likely environmental impacts of dissemination of GIFT were further appraised, and guidelines were drawn up for responsible introduction and use of GIFT. The conclusion was that responsible development and dissemination of GIFT would be unlikely to cause serious environmental impacts.[70] In particular, a review commissioned through DEGITA (footnote 17[ii]) on alien aquatic species in Asia concluded that: "popularization (of GIFT), accompanied with proper management of culture practices is unlikely to harm biodiversity and/or environmental integrity."[71] A more recent global review of the environmental impacts of tilapia has strengthened this conclusion, showing that Nile tilapia, although potentially invasive as an alien species, has had far fewer adverse environmental impacts than other tilapia species introduced and disseminated for aquaculture.[72] Nevertheless, all international

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[69] ICLARM. 1992. *International Concerns in the Use of Aquatic Germplasm*. Manila.

[70] Bentsen, Hans, Trygve Berg, and Peter Johan Schei. 1992. *Environmental Effects of Release and Dissemination of Improved Nile Tilapia*. Report prepared by the Agricultural University of Norway for the UNDP, Division for Global and Interregional Programmes. 10 p.

[71] Da Silva, Sena. (undated). *Popularization of Genetically Improved Oreochromis niloticus ("GIFT fish") in Asia: Environmental Considerations*. Warrnambool, Victoria: Deakin University.

[72] Pullin, Roger, Maria Lourdes Palomares, Christine Casal, Madan Dey, and Daniel Pauly. 1997. Environmental Impacts of Tilapias. In *Tilapia Aquaculture. Proceedings from the Fourth International Symposium on Tilapia in Aquaculture*. Volume 2, edited by Kevin Fitzsimmons. Ithaca, New York: Northeast Regional Agricultural Engineering Service Cooperative Extension. p. 554–570.

introductions of tilapia during the TA were planned and implemented under the highly precautionary policies of ICLARM.[73] None was a first introduction to any country of Nile tilapia as an alien species, and strict quarantine measures were applied. To date, there have been no reports of adverse impacts of GIFT and GIFT-derived Nile tilapia on the environment and on biodiversity, although monitoring must continue as further genetic improvement and dissemination of farmed tilapia proceed.

One cause for concern is that, despite the continuing efforts of the developers and stewards of GIFT genetic resources to discourage the introduction of GIFT to African waters where they would likely interbreed with and compromise the genetic integrity of important wild tilapia genetic resources,[74] there are indications that the Asian private sector has already begun to sell GIFT to some African countries and indeed to any country wishing to buy GIFT. There are legitimate related issues here over benefit sharing. Africa supplied Nile tilapia genes for the development of GIFT, and now seeks to share the benefits of GIFT R&D. However, such benefit sharing can be addressed by disseminating and providing support for the application of GIFT methods to new tilapia breeding programs in Africa that are based on African strains, and not by shipping GIFT directly from Asia to Africa.[75] The WorldFish Center has substantial ongoing programs, supported by UNDP, for transferring GIFT-related technologies from Asia to Africa (currently including Côte d'Ivoire, Egypt, Ghana, and Malawi) for their use with native African tilapia.[76] Nevertheless, given the continuing lax attitudes to controls and safeguards for much of the world's international trade in live fish, both farmed and aquarium species, it is probable that GIFT and GIFT-derived strains will be sought and tried out in African and other tilapia farming countries without adequate prior assessment of environmental impacts.

Farming of tilapia does not generally pose adverse environmental impacts. However, poor fish husbandry practices (as in all forms of fish farming) can contribute to water pollution (footnote 15). Discharges of nutrient-rich water from groups of

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[73] Pullin, Roger. 1994. Exotic Species and Genetically Modified Organisms in Aquaculture and Enhanced Fisheries: ICLARM's Position. *Naga, ICLARM Quarterly* 17(4): 19–24.

[74] WorldFish Center. 2002. *Nairobi Declaration. Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species for Aquaculture in Africa*. Penang.

[75] See for example: Pullin, Roger, Christine Casal, and Randall Brummett. 2001. Fish Genetic Resources of Africa. In African Fish and Fisheries-Diversity and Utilisation, edited by Paul Skelton and Guy Teugels. *Annales Sciences Zoologiques. Royal Museum for Central Africa* 288: 60–74.

[76] Source: WorldFish Center, Penang.

medium- and large-scale ponds into watercourses can cause pollution (high biochemical oxygen demand and elevated nitrogen, phosphate, and suspended solids). Daily application of large quantities of artificial feeds to fish cages in water bodies can place large nitrogen and phosphorus loadings on the water. Good husbandry and environmentally friendly farming practices are key requisites for minimizing adverse environmental effects from tilapia farming.

LESSONS LEARNED

GENETIC IMPROVEMENT AND DISSEMINATION OF TILAPIA BREEDS

R&D in tilapia genetics and dissemination of improved tilapia breeds require long-term and sustained investments. For tilapia, which reach maturity at an age of about 6 months, rapid genetic gains can be achieved. However, the development of GIFT and their uptake in national tilapia breeding programs took at least 10 years. The dissemination of improved tilapia breeds then took place rapidly to generate substantial impacts in countries that participated in this effort. Once developed, improved tilapia breeds and sustained national tilapia breeding programs can significantly and rapidly improve the yields and productivity of tilapia farms.

The GIFT experience shows that in the Asia and Pacific region, substantial external TA and sustained funding were required for at least 10 years to cover the broad spectrum of germplasm collection, application of breeding methods and other protocols, on-station and on-farm trials, consolidation of research results, establishment of networks and national fish breeding programs, and distribution of improved breeds to hatcheries and fish farmers. In addition, promoting the use of improved tilapia breeds for farm production required complementary access to and investments in farm financing, support services, infrastructure, and marketing networks. Gene banking, biosafety and quarantine arrangements, certification of strains, and capacity building are other vital investment areas, but recognition of this, and provision of funding in these areas have so far been inadequate.

In the Philippines (Appendix 2) and Thailand (Appendix 4), the use of GIFT has significantly enhanced tilapia production, generated employment, raised farm incomes from hatcheries and farms, and increased household consumption of tilapia. At the institutional level, GIFT development and dissemination catalyzed the (i) development of networks at the international and local levels; (ii) implementation of national fish breeding programs; (iii) emergence of public-private partnerships; and (iv) development of policies and plans for the expansion of tilapia farming in several countries, viz., Philippines, Thailand, and Viet Nam.

The development and dissemination of GIFT have shown that selective breeding is a feasible and cost-effective approach to the

genetic improvement of tropical farmed fish. GIFT were developed without the need for any application of controversial biotechnology or genetic modification. Selective breeding has been the basis of almost all domestication and genetic improvement of farmed plants and animals in the past. The same approach has been successfully used for tilapia. GIFT have not only generally performed better than existing farmed tilapia, but have also served as good genetic material for continued selective breeding. This recognition is seen in the current use of GIFT and GIFT-derived strains in the national tilapia breeding programs of Bangladesh, Fiji Islands, Philippines, Thailand, and Viet Nam, among other countries, as well as in the application of GIFT-related methods to ongoing genetic improvement of farmed fish in these and other countries as noted earlier.

The GIFT experience has shown that systematic assessments of the performance of genetically improved farmed fish under diverse conditions must precede their commercial production. Multidisciplinary expertise is needed to assess the economic viability, social acceptability, environmental compatibility, and the overall impact of genetically improved farmed fish. It is important to develop the skills and provide adequate resources for these assessments.

The GIFT experience also underscores the need—for credibility purposes—for analyzing and publishing in peer-reviewed scientific journals the genetic gains achieved by GIFT over existing Asian farmed tilapia strains. This activity was not fully achieved in the past, but the WorldFish Center and AKVAFORSK are now rectifying this shortfall through forthcoming publications (footnote 28). Adequate data analysis and preparation of publications should be built into genetic improvement research at the outset.

PARTNERSHIPS AND NETWORKING

Multilevel partnerships and broad-based networks that are driven by common objectives and mutual commitments are highly valuable mechanisms for developing and disseminating genetically improved farmed fish strains, such as GIFT. INGA's global partnerships, along with national research and seed and broodstock distribution networks in major tilapia producing countries (viz., Philippines and Thailand), have accelerated the wide use of GIFT and GIFT methods, and the spread of improved hatchery and farming practices. Public-private partnerships, moreover, have been instrumental in the sharing of resources, expertise, and information in support of tilapia breeding, seed production, and farming.

THE ASIAN DEVELOPMENT BANK'S CATALYTIC ROLE

ADB supported pioneering efforts for the development and dissemination of GIFT by providing TA totaling $1,075,000. Although ADB's financial contribution represented only 14.7% of the combined financial resources made available over the 10-year period 1988–1997 (footnote 18) for the development and dissemination of GIFT, ADB's TA was instrumental in catalyzing the development of broader multinational partnerships and networks, and in galvanizing further support to promote and recognize the importance of genetic improvement of farmed fish and national fish breeding programs for the development of aquaculture. ADB's TA has had high leverage, and has generated significant long-term favorable outcomes and impacts on capacity development, transfer of knowledge and technology, and policies and socioeconomic conditions in terms of tilapia production, farmers' incomes, employment generation, and human nutrition. This development experience, and the context in which ADB pioneered, designed, and delivered its TA in partnership with ICLARM with broad international support, should be considered as an example of good practice.

Effectiveness of Technical Assistance. This IES examined the ADB-financed TA (footnote 17) as a continuum of activities in the context of broader R&D objectives (para. 8) with extensive international collaboration and aid coordination. Outcomes and impacts of the development and dissemination of GIFT cannot be attributed to this TA alone. With common strategic objectives, collective efforts and strong partnerships among international and national researchers, developers, and practitioners were the main driving force for achieving results together. The TA was assessed as (i) highly relevant to these strategic objectives; (ii) efficacious in the context of its achievement of purpose; and (iii) highly efficient in its function as a catalyst with high leverage to promote support, investments, and recognition for the importance of R&D. The TA had been an important part of a critical process that resulted in sustained efforts for continuing R&D and dissemination of GIFT and GIFT-derived strains. The outcomes and impacts of the R&D efforts are substantial and will most likely be sustained. Overall, the IES has rated the ADB-financed TA as highly successful.

BIOSAFETY AND ENVIRONMENTAL SAFEGUARDS

Biosafety, quarantine, and other environmental safeguards have not yet been adequately applied in many developing countries with respect to aquaculture development and related research. International transfers and domestic distribution of alien species and of genetically improved farmed fish, among and within such countries, can put at risk entire aquaculture sectors through the spread of diseases and parasites. At similar risk are natural aquatic environments and their biodiversity, again through diseases and parasites, and also through predation, competition for food and spawning habitats, hybridization, and habitat modification.

To date, the development and dissemination of GIFT, GIFT-derived, and other Nile tilapia do not appear to have caused any significant adverse impacts on existing aquaculture or on the natural environment and biodiversity in the Asia and Pacific region. However, the region has a wealth of freshwater biodiversity and habitats, and adequate areas containing this natural heritage should, where possible, be kept off limits to aquaculture, whether of native or alien species, including tilapia. Such areas would contain the wild genetic resources for future breeding programs of Asian farmed fish, and would serve as in situ gene banks for this purpose. This could be achieved by combining appropriate policies, rules, and regulations, as well as implementation, management, and administration practices for aquaculture development with long-term safeguarding and conservation of aquatic biodiversity and habitats.

SUSTAINABILITY

Experience with GIFT and GIFT-derived strains has shown that key enabling conditions must be in place in a country for the development and dissemination of genetically improved farmed fish to succeed and to be sustainable. These conditions include (i) the existence of a strong national institute, with adequate capabilities in fish genetics research; (ii) adequate resources and continued commitments for implementing national fish breeding programs; (iii) multilevel networks and broad-based partnerships (including those between private and public institutions) for production and distribution of genetically improved broodstock and seed; (iv) market-driven demand for the farmed species concerned and prospects for gaining attractive returns from fish farming; (v) supportive policies, facilities, and infrastructure for fish farming; (vi)

access by fish farmers to livelihood assets (footnote 15: human, social, natural, physical, and financial capital) and to support services; and (vii) enforcement of biosafety and environmental safeguards. Policies and investments to ensure fulfillment of these enabling conditions are key to sustained genetic improvement in aquaculture and to sustained benefits for producers, intermediaries, and consumers.

RECOMMENDATIONS

Support Wider and Sustained Application of Genetics in Aquaculture. The application of genetics in aquaculture still lags far behind its application in terrestrial crops and livestock. As evidenced through the development of GIFT, the rewards for aquaculture from public and private investment in genetic improvement of farmed fish can be substantial. This applies not only in Asia, which is likely to continue to supply over 80% of the world's farmed fish, but in all regions, as wild fisheries reach their limits or decline. The need for increased investment in fish genetic resources conservation, combined with their use in genetic improvement research and fish breeding programs, is extensive and immediate. The long-term future of Asian-Pacific aquaculture will depend on wise choices of fully domesticated and genetically improved breeds of farmed fish that can be produced efficiently in response to expanding markets. ADB should support further collaborative efforts to (i) identify further opportunities for the application of genetics in Asian-Pacific aquaculture; and (ii) support R&D on fish breeding, especially for species that can be bred to gain desirable performance traits over short generation times. These efforts would contribute to prioritizing feasible investments in the application of genetics for sustainable aquaculture. This recommendation is consistent with the ADB's Policy on Fisheries.[77]

Increase Support for Application of Genetics in Tilapia Farming in Asia. Tilapia has become an international fish commodity. Global production of farmed tilapia is projected to rise from 1.5 million t in 2003 to 2 million t in 2010.[78] However, intensive feedlot tilapia farming practices, whether in cages, ponds, or tanks, using protein-rich and high-energy formulated feeds (containing fishmeal and marine fish oils) may compromise the tilapia attribute of feeding low in the food chain. There is scope for further genetic improvement of farmed tilapia for improved feed conversion and growth using plant-based feeds, as well as for dressing weight and other performance traits, including cold tolerance and saltwater

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[77] ADB. 1997. *The Bank's Policy on Fisheries*. Manila. According to para. 99 of this policy, several avenues exist for sustainably increasing fish production. The first and most promising is the genetic improvement (and subsequent dissemination) of strains and species with the potential of mass production (such as tilapia), which ADB has been and should continue to support.

[78] Cutland, Laura. 2003. Tilapia. The World's Most Popular Fish? 3 December 2003. Intrafish. Available: www.intrafish.com

tolerance. GIFT and GIFT-derived strains are currently a good basis for the pursuit of further genetic improvement of farmed tilapia, but there is a wealth of other wild and farmed tilapia genetic resources to be assessed as breeding material. National programs should develop research strategies to maintain the integrity of improved tilapia strains and to maintain the characteristics of farmed tilapia that have hitherto made them so appropriate and accessible for both farmers and consumers, including the poor. In partnership with other institutions, ADB should consider providing further support to its developing member countries to establish self-sustaining national tilapia breeding programs and related research to (i) improve the performance of broodstock and farmed tilapia strains; (ii) promote appropriate dissemination channels; and (iii) enhance market intermediary mechanisms to ensure farmers, including the poor, wider access to affordable seed. Current ADB Country Strategy and Programs and Regional Country Strategy and Programs have not indicated further support to establish self-sustaining national tilapia breeding programs and related research in relevant countries.

Strengthen Links Between Tilapia Genetic Research and the Dissemination of Improved Strains through Networks and Public-Private Partnerships. Institutional, technical, and socioeconomic constraints can adversely affect development of improved tilapia breeds and their dissemination to farmers. It is not sufficient to have strong research institutes for tilapia genetics research and breeding when intermediary channels for delivering products and services to farmers as ultimate users are deficient. While it is important to have well-established networks to hasten transfer of good quality tilapia germplasm, strengthening links between research and dissemination, and promoting an enabling environment for tilapia farming to thrive are both central to the expansion of farmed tilapia production. Future efforts need to further promote and galvanize (i) public-private partnerships in tilapia research and information exchange, (ii) commercial alliances and partnerships in seed production and distribution to respond to increasing demands for tilapia seed, and (iii) tilapia marketing to meet growing domestic demands for fish and the potential for exports. To avoid potential conflicts of interest between the public and private sectors, concerned parties must carefully delineate and comply with their respective roles to ensure that the public sector does not stifle the interests of the private sector, and to provide fish farmers, including the poor, with access to good and affordable tilapia seed.

Invest in the Conservation of Wild and Farmed Tilapia Genetic Resources. Despite the proven genetic variability of GIFT, there are extensive tilapia genetic resources in Africa that have yet to

be investigated as breeding material for the development of farmed tilapia. There is scope for interregional collaboration between African countries that contain the world's most important wild tilapia genetic resources, but lack adequate numbers of trained fish geneticists and breeding facilities, and Asian and other countries that are now leaders in tilapia farming and breeding, based on historic genetic transfer from Africa. The development of GIFT relied on the availability of wild tilapia genetic resources from Africa and farmed tilapia strains in Asia. This suggests that, in all regions, the genetic improvement of tilapia and the expansion of breeding for tilapia farming should be undertaken in parallel with conservation of tilapia genetic resources in situ in the waters of Africa and ex situ on farms, in broodstocks, and in gene banks. Consequently, all countries farming tilapia should strive to keep some of their waters that contain important aquatic biodiversity and genetic resources off-limits for aquaculture and isolated from all possible contact with farmed fish.

Safeguard Tilapia Farming and Its Gains. Tilapia farming is undergoing a major expansion worldwide and is contributing significantly to food security, incomes, and employment. In common with all food production through farming, tilapia farming faces some unavoidable risks and uncertainties, such as long-term climatic and short-term weather effects due to changes in rainfall and temperature and to severe storms. Tilapia farming is also jeopardized by ineffective quarantine; by irresponsible fish introductions, releases, and escapes; and by poor husbandry.[79] Effective biosafety measures to safeguard tilapia farming and reliable arrangements for the certification of tilapia strains are priorities for policymakers to consider and for national program and tilapia farming entities to implement. All countries farming tilapia should recognize the above risks and take steps to educate and encourage the participation of all stakeholders to safeguard the future of tilapia farming as it expands. These parties include researchers, tilapia seed producers, intermediaries, and fish farmers, both public and private, rich and poor.

[79] The most obvious risks include potential mass outbreaks of disease and parasitic infestations. Taking into account the ease with which tilapia interbreed, tilapia broodstock and breeding programs should be responsibly managed, and claims about the identity and provenance of tilapia seed and broodstocks must be reliable.

Appendixes

APPENDIX 1

International Network on Genetics in Aquaculture and Genetic Improvement of Farmed Tilapia Foundation International Incorporated

This appendix describes the functions and operations of the International Network on Genetics in Aquaculture (INGA) and the Genetic Improvement of Farmed Tilapia Foundation International, Incorporated (GFII) and highlights their roles in further development and dissemination of genetically improved farmed tilapia (GIFT). A technological breakthrough came out of selective breeding efforts to develop GIFT (1988–1992, Phase 1), which was made possible through technical assistance (TA) funded by the Asian Development Bank (ADB), the United Nations Development Programme (UNDP), and participating institutes.[1] A breakthrough such as this called for complementary structures for enhancing and sustaining GIFT-related efforts. UNDP provided further TA for the development of GIFT (1993–1997, Phase 2), which led to the establishment of INGA and GFII (footnote 1[i]). In parallel, ADB provided further TA from 1994 to 1997 to disseminate GIFT to various countries.[2] ADB complemented UNDP's continued support for the development of GIFT over the same period.

INTERNATIONAL NETWORK ON GENETICS IN AQUACULTURE

Background. UNDP recognized that GIFT and GIFT-related technology and information were creating, for the first time in the history of tropical aquaculture, a situation similar to that for the international evaluation of improved terrestrial crop varieties. In 1993,

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1 (i) Eknath, Ambekar, and Belen Acosta. 1998. *Genetic Improvement of Farmed Tilapia Project: Final Report (1988–1997) to the United Nations Development Programme (Project No. GLO/90/0160).* Part I. Manila: ICLARM.
(ii) TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988.

2 TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia*, for $600,000, approved on 14 December 1993.

UNDP provided $65,000 for the establishment of INGA, patterned after the UNDP-funded International Network for Genetic Evaluation of Rice, which had earlier demonstrated the effectiveness of networking for rice genetic improvement. INGA started in July 1993 with 11 developing member countries (Bangladesh, the People's Republic of China [PRC], Côte d'Ivoire, Egypt, Ghana, India, Indonesia, Malawi, Philippines, Thailand, and Viet Nam) and with International Center for Living Aquatic Resources Management (ICLARM, now the WorldFish Center) as member-coordinator.[3] The Fiji Islands and Malaysia joined INGA in 1996. Based in Penang, Malaysia, at the headquarters of the WorldFish Center, INGA currently has 12 advanced scientific institutional members across the globe: Agricultural Research Organization, Israel; Auburn University, United States; Fish Culture Research Institute, Hungary; Food and Agriculture Organization of the United Nations; Institute for Aquaculture Research (AKVAFORSK), Norway; National Research Institute of Aquaculture, Japan; Queensland University of Technology, Australia; Aquaculture Department, Southeast Asian Fisheries Development Center, Philippines; University of Stirling, United Kingdom; University of Wales, Swansea, United Kingdom; Wageningen Agricultural University, Netherlands; and WorldFish Center, Malaysia. In addition, three organizations are associate members: Asian Institute of Technology, Thailand; GFII; and University of Western Australia, Australia.[4]

Mandate. As an international network, INGA's mandate includes strengthening national research capacities for application of genetics in aquaculture; fostering regional and international cooperation; and assisting the development of national fish breeding programs, with a focus on tilapia and carps. INGA also strives for conservation of biodiversity in farmed and wild populations of tilapia, carps, and other fish species.

Operations. Since 1993, INGA has provided international partnerships and links for the dissemination, information exchange, and further development of GIFT.[5] Its developing member countries

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[3] Gupta, Modadugu, and Belen Acosta. 1999. *International Network on Genetics in Aquaculture: A Global Forum for Collaborative Research and Training in Applied Fish Breeding and Genetics*. Manila: ICLARM.

[4] WorldFish Center. 2003. *International Network on Genetics in Aquaculture: Final Report (July 2001 to December 2003)*. Report submitted to the Norwegian Agency for Development Cooperation. Penang.

[5] Gupta, Modadugu, and Belen Acosta. 2001. Networking in Aquaculture Genetics Research. In Fish Genetics Research in Member Countries and Institutions of the

identify projects appropriate to their national priorities, many of which are common to regional or subregional groups of members. INGA has assisted its members and other countries in sharing GIFT and other farmed fish germplasm for research, use in national tilapia breeding programs, and dissemination to farmers. From 1994 to 2003, INGA facilitated the transfer of 133,494 tilapia as germplasm for these purposes. These transfers comprised 70,913 GIFT and 62,581 other tilapia (Tables A.1.1 and A1.2). All transfers were made under voluntary INGA protocols for biosafety, including quarantine, derived from the procedures adopted during acquisition of tilapia germplasm from Africa, for the development of GIFT (footnote 1[i]). Dissemination of GIFT and other tilapia germplasm has involved Bangladesh, PRC, Côte d'Ivoire, Egypt, Fiji Islands, India, Indonesia, Kenya, Lao People's Democratic Republic, Malaysia, Papua New Guinea, Thailand, and Viet Nam.

Table A1.1: Tilapia Germplasm Transfers Facilitated Through INGA, 1994–2003

	Number of Fish Distributed	
Destination Country	**GIFT Strain**	**Other Strains**
Bangladesh	2,163	8,000
PRC	5,100	
Egypt		481
Fiji Islands	1,600	
India	3,000	
Indonesia	6,000	
Jordan		30,000
Lao PDR		2,000
Malaysia	22,000	16,000
Philippines		
Sri Lanka	1,500	
Thailand	19,050	5,000
Viet Nam	10,500	1,100
Total	**70,913**	**62,581**

INGA = International Network on Genetics in Aquaculture; Lao PDR = Lao People's Democratic Republic; PRC = People's Republic of China.
Source: INGA Secretariat.

International Network on Genetics Research in Aquaculture, edited by Modadugu Gupta and Belen Acosta. *ICLARM Conference Proceedings* 64. p. 1–5. Manila.

Table A1.2: Sources of Tilapia Germplasm Transfers Facilitated Through INGA, 1994–2003

Sources	GIFT Strain	Other Strains
GIFT Project, Philippines	65,913	5,100
GFII, Philippines	5,000	6,650
Egypt		9,000
Côte d'Ivoire		81
Kenya		400
Research Institute for Aquaculture No. 1, Viet Nam		2,000
ICLARM-Regional Center for Africa and West Asia (Abbassa, Egypt)		30,000
Total	**70,913**	**62,581**

GFII = Genetic Improvement of Farmed Tilapia Foundation International Incorporated, GIFT = genetically improved farmed tilapia, ICLARM = International Center for Living Aquatic Resources Management, INGA = International Network on Genetics in Aquaculture.
Source: INGA Secretariat.

INGA has facilitated the formation of national networks for genetics in aquaculture in India, Indonesia, Malaysia, and Philippines and has contributed to the strengthening of national institutes through regional workshops, training courses, exchange, and research internships in quantitative genetics, broodstock management, GIFT breeding procedures, analysis of breeding data, and molecular genetics. Since 1995, 219 persons from 28 countries in Asia, Africa, and Latin America have benefited from training conducted under the auspices of INGA.[6] INGA has also assisted its tilapia-farming member countries in the development of breeding programs. In Bangladesh, Fiji Islands, Philippines, Thailand, and Viet Nam, these breeding programs and related genetics research are now based mainly or exclusively on GIFT or GIFT-derived strains and on the methods used to develop GIFT. GIFT are also used extensively in research for development of tilapia farming in the PRC, Indonesia, and Malaysia. INGA, moreover, has facilitated the implementation of ADB-financed regional TA for the genetic improvement of carps farmed in Asia, following largely the same approaches as were used for the development and dissemination of GIFT.[7]

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6 Source: WorldFish Center, Penang.

7 (i) TA 5711-REG: *Genetic Improvement of Carp Species in Asia*, for $1.3 million, approved on 12 December 1996.

INGA members publish news on research advances and related development and policy issues in the *WorldFish Center Quarterly*, *Naga*, and in special publications and on the INGA web site.[8] INGA also facilitates expert consultations on key policy issues, for example, ecological risk assessment for the use of genetically improved fish and alien species in aquaculture.[9]

INGA's strengths lie primarily in its broad-based, inclusive networking, its participatory mode of operations, and the complementarity of skills among its members. However, limited financial and human resources are now constraining INGA's operations. Financial assistance from the Norwegian Agency for Development Cooperation ended in December 2003. INGA has continued to seek funding from other aid agencies. The WorldFish Center currently supports INGA from its core funds.

GENETIC IMPROVEMENT OF FARMED TILAPIA FOUNDATION INTERNATIONAL INCORPORATED

Background. After the completion of TA to develop and to disseminate GIFT (footnotes 1[ii] and 2), the chief concern among the participating institutes and funding agencies was how to keep intact the highly trained technical team in the Philippines that developed GIFT, so as to develop GIFT further and to widen access to GIFT and GIFT-related methods and training. There was also the need to provide for the long-term management of the valuable gene bank of GIFT broodstock and cryopreserved sperm that had been developed. All of the above were considered vital for the continuation of the Philippine national tilapia breeding program, and for further development and use of GIFT and GIFT-related methods in other countries. The partner institutes that had developed and disseminated GIFT, in consultation with UNDP, decided that these provisions could best be made by establishing a new structure that would hasten the commercialization of GIFT, taking into account various assets that were available at the conclusion of the TA and of UNDP support. These assets comprised principally leased facilities,

(ii) TA 6136-REG: *Achieving Greater Food Security and Eliminating Poverty by Dissemination of Improved Carp Species*, for $0.95 million, approved on 11 November 2003.

8 http://www.worldfishcenter.org/inga

9 INGA and WorldFish Center. 2003. *Dhaka Declaration on Ecological Risk Assessment of Genetically Improved Fish*. Penang: International Network on Genetics in Aquaculture and WorldFish Center.

human resources, equipment, and GIFT germplasm for further selective breeding. This new structure was GFII.

Mandate. GFII was incorporated in the Philippines in 1997 as a nonstock, nonprofit foundation to distribute GIFT on a commercial scale and to continue selective breeding efforts with GIFT. The GFII incorporators were the senior executives of the Bureau of Fisheries and Aquatic Resources of the Philippines, Central Luzon State University (Philippines), and ICLARM, whose successors retain permanent ex-officio seats on the GFII Board of Trustees. In 1998, GFII occupied 8 hectares of land and facilities within the Center for Applied Fish Breeding and Genetics at Central Luzon State University (footnote 1[i]). GFII took over management of the GIFT breeding nucleus and related germplasm, and employed the highly trained Philippine technical staff who had participated in the development of GIFT.

Operations. GFII financed its operations initially through fees charged to GIFT-accredited partner hatcheries, by selling from its own premises GIFT seed and broodstock, and by providing technical services and training. In 1998, it entered into partnerships with seven privately owned tilapia hatcheries in nearby Philippine provinces through formal licensing arrangements.[10] By the end of 2001, it had disseminated 522,700 GIFT as broodstock to these accredited private hatcheries.

In 1999, GFII drew up an agreement with Genomar ASA (formerly Biosoft ASA) of Norway, under which GFII and Genomar ASA agreed to pursue collaborative research for further genetic improvement of GIFT in the Philippines, allowing exclusive rights to Genomar ASA for commercialization of the resulting new GIFT generations. Under this agreement, GFII contributed tilapia breeding stock and other assets to Genomar ASA in exchange for an equity position in Genomar ASA. This commercial alliance was aimed at intensifying commercialization and dissemination of high-performance tilapia seed to fish farmers to meet the demand for food fish for the growing population. GFII also retained its own historical GIFT broodstock to continue independent research and development (R&D). Under its agreement with Genomar ASA, GFII can conduct its own independent R&D, provided that Genomar ASA is informed of and invited to participate in such research. If Genomar ASA declines

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[10] Acosta, Belen, and Modadugu Gupta. 2004. Public-Private Partnerships for Tilapia Genetics Research in the Philippines: Case Study on GIFT and Lessons Learned. Paper presented at the Workshop on Public-Private Partnerships in Tilapia Genetics and Dissemination of Research Outputs: Philippine Experience, 21–23 January 2004, Tagaytay City, Philippines. CD-ROM. Penang: WorldFish Center.

to participate, GFII is free to seek other partners. New GIFT generations bred by GFII and commercialized by Genomar ASA have been produced in Genomar-accredited hatcheries in the Philippines and sold as Genomar Supreme Tilapia™.[11] Genomar's operations in production and marketing of GIFT-based fish seed have also expanded to Bangladesh, the PRC, and Thailand.

International and Philippine national affiliations, together with its skilled staff, have positioned GFII as a provider of training for tilapia genetic improvement and breeding programs. In collaboration with the WorldFish Center and INGA, GFII trains operators of tilapia hatcheries and staff of national institutes in selective breeding, broodstock management, seed production, and sex reversal. Up to April 2004, GFII had provided training for persons from the Asia-Pacific region as follows: Bangladesh, 19 trainees; Malaysia, 36; Papua New Guinea, 3; Philippines, 32; and Viet Nam, 18. Over the same period, 15 trainees from INGA member countries in Africa (Côte d'Ivoire, Egypt, Ghana, Malawi, and South Africa) received training from GFII in selective breeding. On a wider front, GFII is an associate member of INGA and is a partner in a multi-institute Tilapia Science Center in the Philippines, which has been the prime mover in the establishment a national tilapia trade association (Philippine Tilapia, Inc.) and a major player in the development of private-public partnerships in tilapia genetic improvement.

[11] Available: http://www.genomar.no/section.cfm

APPENDIX 2

Impacts of Genetically Improved Farmed Tilapia in the Philippines

TILAPIA FARMING: RELEVANCE OF GENETIC IMPROVEMENT RESEARCH

Purpose and Scope. This appendix reviews impacts in the Philippines of genetically improved farmed tilapia (GIFT), a product of research and development (R&D) efforts supported by technical assistance financed by the Asian Development Bank and others in 1988–1997.[1] The tilapia strains that were bred and disseminated through these efforts are called GIFT, as are any tilapia bred subsequently using only GIFT genetic material. Tilapia that have been bred by combining GIFT and other tilapia genetic material are called GIFT-derived.[2]

Methods and Sources. Qualitative and quantitative methods were used, namely (i) a review of existing studies and secondary documents, (ii) a national survey of tilapia hatcheries, and (iii) semistructured interviews with key informants. The survey covered the two primary tilapia farming regions—central Luzon (Region III) and southern Luzon (Region IV)—and the four secondary tilapia farming regions: northern Luzon (Regions I and II); Bicol (Region V); and, in Mindanao, the region comprising the provinces of South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos. Hatcheries were initially categorized by fry and fingerling production capacity per year as (i) small, fewer than 12 million; (ii) medium, 12–60 million; and (iii) large, more than 60 million. All known hatcheries within the medium and large categories were included in the survey, with small hatcheries chosen at random. The total sample comprised 136 hatcheries: 125 private hatcheries, 7 government hatcheries, and 4 tilapia breeding centers. The current total number of tilapia hatcheries in the Philippines, including all small establishments, is

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1 (i) TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988. This R&D effort was also supported by the United Nations Development Programme and research partner institutes.
(ii)TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia*, for $600,000, approved on 14 December 1993.

2 No references are made in this report to specific generations of GIFT because there is no standard nomenclature for these. All GIFT are regarded here as a genetically improved breed of Nile tilapia, still under development.

not documented but has been estimated at about 600.[3] The Statistical Package for Social Sciences was used to process the survey data, to generate descriptive and inferential statistics, and to test for statistical significance of differences.

History of Tilapia Breeding. Tilapia farming in the Philippines began with the introduction of the Mozambique tilapia (*Oreochromis mossambicus*) from Thailand in 1950. It soon acquired a bad reputation because of slow growth and prolific, precocious spawning, which led to overcrowding of fishponds with small fish. Interest in tilapia farming was revived with introductions of the Nile tilapia (*O. niloticus*) in the early 1970s because of its faster growth and more appealing, light color. Increased R&D followed on tilapia seed production and growout, including technology for producing all male, sex-reversed tilapia (SRT).[4] The breeding of tilapia families in individual fine mesh cages (termed *hapas*) and improved pond and cage husbandry were important contemporary technological advances. Tilapia seed is produced in hatcheries and nurseries from broodstock that are kept in breeding ponds or *hapas*. Tilapia are farmed as monocultures (no other fish species present), mainly in ponds and cages. Since the 1980s, production of farmed tilapia in the Philippines has increased markedly, particularly from freshwater ponds and cages (Figure A2.1). Its growth began to accelerate after 1988, catalyzed mainly by the results of increased R&D, including the development and dissemination of GIFT. In 2002, freshwater ponds (mainly in central and northern Luzon) produced 65,968 tons (t) of farmed tilapia; freshwater cages (mainly in Lake Taal, Batangas, and in various lakes in Luzon and Mindanao) produced 46,330 t, representing 54% and 38%, respectively, of the national production of farmed tilapia (122,277 t).[5]

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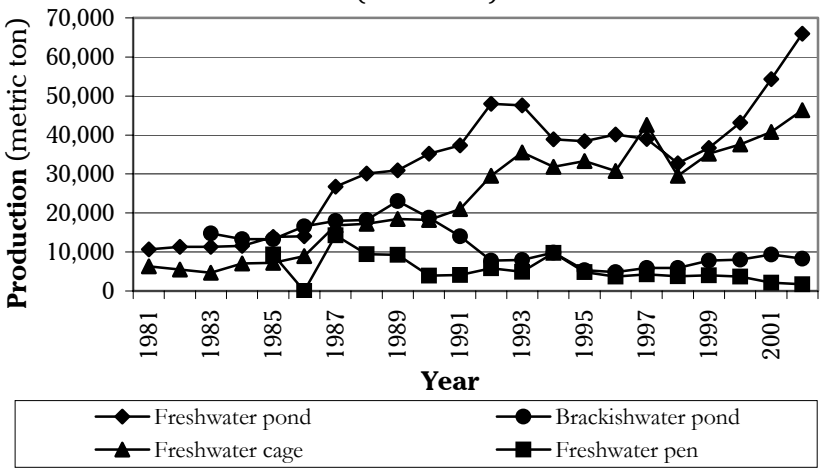
[3] Basilio Rodriguez Jr., Genetic Improvement of Farmed Tilapia Foundation International, Incorporated.

[4] Seed means fry and fingerlings. Growout means the raising of seed to harvestable size. Male tilapia grow faster than females and mixed sex tilapia populations in ponds mature early and reproduce prolifically. SRT fry receive, for a short period, feeds containing methyltestosterone, posing no risks to consumers.

[5] Bureau of Agricultural Statistics. 2003. *Fisheries Situation.* Vol. 7, No. 10. January–December 2002. Quezon City.

Figure A2.1: Farmed Tilapia Production in the Philippines, 1981–2002
(metric ton)



Source: Bureau of Agricultural Statistics.

ENABLING AND SUSTAINABILITY FACTORS

Tilapia Introductions. Since 1972, there have been numerous introductions of Nile tilapia to the Philippines (Table A2.1). It remains the only important farmed tilapia, despite introductions of other tilapia species and hybrids. The Philippines was the host country for the development of GIFT and became, in 1993, the first country to have GIFT available for national trials and dissemination. The 1988–1989 introductions of Nile tilapia for the development of GIFT were the only ones made directly from Africa, the world's sole source of pure strains of wild tilapia. Wild strains were collected across the natural range of Nile tilapia in Africa, and evaluated together with Nile tilapia strains then being farmed in the Philippines. Genetic material from the best performing wild and farmed Nile tilapia strains was combined to create a synthetic base population, from which GIFT were developed by selective breeding.[6] GIFT have higher genetic variability than do other tilapia in the Philippines.[7] This indicates their

[6] Eknath, Ambekar, and Belen Acosta. 1998. *Genetic Improvement of Farmed Tilapia Project: Final Report (1988–1997) to the United Nations Development Programme (Project No. GLO/90/0160)* Part I. Manila: ICLARM.

[7] Romana-Eguia, Maria Rowena, M. Ikeda, Zubaida Basiao, and Nobuhiku Taniguchi. 2004. Genetic diversity in farmed Asian Nile and red hybrid tilapia stocks evaluated from microsatellite and mitochondrial DNA analysis. *Aquaculture* 236: 131–150.

suitability for improvement of diverse performance traits, by selection.

Table A2.1: Important Introductions of Nile Tilapia to the Philippines, 1972–1993

Strain	Year	Source	Recipients	Purpose
Thailand	1972	Thailand	BFAR	Production
Israel (origin Uganda)	1972	Israel	Laguna Lake Development Authority	Production
Ghana	1977	Israel	CLSU	Research
	1977	Singapore	BFAR	Research
	1979	Taipei,China	Southeast Asian Fisheries Development Center	Research
	1979	Israel	CLSU ICLARM (now the WorldFish Center)	Research
Egypt[a]	1988–1989	Egypt	BFAR ICLARM (now the WorldFish Center)	Research
Ghana[a]	1988	Ghana	Ditto	
Sénégal[a]	1988	Sénégal	Ditto	Research
Kenya[a]	1989	Kenya	Ditto	Research
Swansea (origin Egypt)	1988–1993	Wales, United Kingdom	CLSU	Research

BFAR = Bureau of Fisheries and Aquatic Resources, CLSU = Central Luzon State University, ICLARM = International Center for Living Aquatic Resources Management

[a] Wild strains, direct from Africa.

Source: Freshwater Aquaculture Center of Central Luzon State University.

Institutional Settings. Policymaking, planning, and administration of Philippine fisheries and aquaculture have a history of institutional complexity and change. In 1983, the Food and Agriculture Organization of the United Nations, during a high-level exclusive economic zone mission, identified 22 national, 2 regional, and 2 international institutions involved in Philippine fisheries.[8] The Philippine Council for Aquatic and Marine Research and Development (PCAMRD), created in 1987, was mandated to provide direction for fisheries and aquatic resources R&D in the national research system. PCAMRD implements its mandate through systematic planning, monitoring, evaluation, and coordination within a National Aquatic Resources Research and Development System

[8] Cited in BFAR. 1987. *Main Report: National Conference on Fishery Policy and Planning.* Quezon City, Philippines: Bureau of Fisheries and Aquatic Resources, Department of Agriculture.

network of centers and stations consisting of state universities and colleges, and through its linkages with the private sector and national and international agencies. Tilapia farming R&D began with the establishment in 1973 of the Freshwater Fish Station at Central Luzon State University (CLSU), Science City of Muñoz, Nueva Ecija. In 1976, this station became the country's Freshwater Aquaculture Center (FAC), administered as part of CLSU. In 1977, the Freshwater Fish Hatchery- Extension and Training Center was established adjacent to FAC and on CLSU land. Under the Bureau of Fisheries and Aquatic Resources (BFAR) of the Department of Agriculture, this center expanded and became the National Freshwater Fisheries Technology Center (NFFTC).

In the late 1970s, poor performance of the Nile tilapia strains available to farmers was attributed to inbreeding and to hybridization with *O. mossambicus*. Tilapia genetic improvement research began in 1979, through collaboration between FAC and the International Center for Living Aquatic Resources Management (ICLARM), and these partners were soon joined by NFFTC. From the 1980s, research teams from the University of the Philippines and the Aquaculture Department of the Southeast Asian Fisheries Development Center also contributed strongly to tilapia genetic research.[9]

The growth of Philippine tilapia farming in the 1990s was catalyzed largely by the commercial availability of GIFT, GIFT-derived, and other purposefully bred Nile tilapia strains. In 2002, the main organizations involved in tilapia research jointly established the Tilapia Science Center in Muñoz to foster collaboration for development of tilapia farming.[10] The Tilapia Science Center convenes a National Tilapia Congress every 2 years. In 2003, a tilapia trade association, Philippine Tilapia, Inc., was founded. The Department of Agriculture, through BFAR, has also proposed the creation of the Tilapia Council of the Philippines as an all-inclusive body to coordinate tilapia-related programs and to review an existing Tilapia Master Plan.[11] Together, these efforts indicate the growing

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[9] Basiao, Zubaida. 2001. Genetics research at the Southeast Asian Fisheries Development Center. In *Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics in Aquaculture*, edited by Modadugu Gupta and Belen Acosta. ICLARM Conference Proceedings 64. p. 141–144. Manila.

[10] The Tilapia Science Center is composed of the FAC and the College of Fisheries of CLSU, NFFTC, GFII, and Phil-Fishgen.

[11] The Tilapia Master Plan, developed by the Department of Agriculture in 2002, envisages growth of farmed tilapia production from 122,000 t in 2002 to 250,000 t in 2010. The Tilapia Road Map, under development by BFAR, includes identification of resources, evaluation of production potentials, analysis of seed demand, identification of problems, and development strategies.

participation of diverse public and private stakeholders in charting the direction of tilapia farming.

Prior to the inception of the technical assistance in 1988 (footnote 1), tilapia introduced to the Philippines were usually kept—without purposeful genetic improvement—to produce seed for research and for dissemination to hatchery operators and farmers, mainly through public sector mechanisms.[12] However, the alliance of FAC and NFFTC on the CLSU campus, their links to a nationwide hatchery network, and their shared experience in conducting aquaculture research on-station and on-farm had long been important factors for the rapid application of research results. These were highly favorable preconditions for development and subsequent dissemination of GIFT.

TILAPIA GENETICS RESEARCH AND BREEDING

In the Philippines, tilapia genetics and breeding research have long received strong and sustained support from external and national funding agencies (Table A2.2). This has enabled the development and current availability to farmers of four main strains of Nile tilapia: (i) Genomar Supreme Tilapia™, a GIFT strain produced by Genomar Supreme Philippines, Inc.; (ii) FAST strain, bred by FAC without use of GIFT genetic material; (iii) the GIFT-derived GET EXCEL strain, developed by BFAR by crossbreeding GIFT with FAST and with GIFT founder stocks from Egypt and Kenya; and (iv) genetically male tilapia (GMT) of the Swansea strain (origin Egypt), produced and distributed by FAC through Phil-Fishgen.[13] The development of GIFT and the external support for their dissemination were catalysts for the decision of the Department of Agriculture to establish and to support a Philippine national tilapia breeding program, based initially on GIFT and later on GIFT-derived strains. The development and dissemination of GIFT were accompanied by on-the-job and formal training for Philippine researchers and technicians and brought about substantial development of national research facilities (experimental ponds, tanks, and laboratories) through external and national funding.

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[12] The main channels for seed dissemination comprised NFFTC; its 13 regional outreach stations; and numerous satellite hatcheries at the provincial, municipal, state university/college, local government unit, and barangay (village) levels.

[13] Available: http://www.mozcom.com/~p-fishgen

Table A2.2: Examples of Major External and National Support for Tilapia Genetics Research and Breeding in the Philippines, 1979–2004

A. External Support

Period	Activities	Funding Agencies and Funds Provided ($)
1979–1981	Mass production of fry	Rockefeller Foundation ($55,742)
1986–1994	Genetic improvement in aquaculture	IDRC, Canada ($81,450)
1988–1992	Breeding GIFT	ADB ($475,000); UNDP ($525,000)
1988–1999	Technology for genetically male tilapia (GMT)	DFID, United Kingdom ($405,902)
1993–1997	Further breeding and dissemination of GIFT	ADB ($600,000); UNDP ($4,307,690); ICLARM ($1,111,234)
1998–2004	Breeding salt-tolerant tilapia	CIRAD, France ($93,050)
2001–2004	Genetic improvement	DFID, United Kingdom ($66,921)

ADB = Asian Development Bank, CIRAD = Coopération Internationale en Recherche Agronomique pour le Développement, DFID = Department for International Development, GIFT = genetically improved farmed tilapia, ICLARM = International Center for Living Aquatic Resources Management, IDRC = International Development Research Centre, UNDP = United Nations Development Programme.

B. National Support

Period	Activities	Funding Agencies and Funds Provided (Pesos)
1993–1995	Genetics and biodiversity	CHED and CLSU (P1 million)
1993–1998	Philippine national tilapia breeding program	DA, through BFAR (P20 million)
1998–2002	Breeding salt-tolerant tilapia	PCAMRD (P1.9 million)
2003–2004	Regional dissemination of GET EXCEL tilapia	DA, through BFAR (P35.7 million)

BFAR = Bureau of Fisheries and Aquatic Resources, CHED = Commission on Higher Education, CLSU = Central Luzon State University, DA = Department of Agriculture, PCAMRD = Philippine Council for Aquatic Marine Research and Development.

This table summarizes support to the Philippine institutes that participated in the development and dissemination of GIFT. The Asian Development Bank and United Nations Development Programme funds listed here are the totals provided to Philippine institutes and others, principally the International Center for Living Aquatic Resources Management (now the WorldFish Center), and the Institute for Aquaculture Research, Norway.

Sources: Bureau of Fisheries and Aquatic Resources; Freshwater Aquaculture Center of Central Luzon State University; Annual Reports (1979–1981) of the International Center for Living Aquatic Resources Management; and Philippine Council for Aquatic and Marine Research and Development.

DISSEMINATION AND EVALUATION OF GIFT

National and Regionwide Trials. Tilapia was identified in the late 1980s as a high priority commodity for national R&D efforts.[14] In 1993, the Philippines became a national program partner in the regionwide Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA, footnote 1[ii]) and the supplier of GIFT to the other four countries participating in DEGITA: Bangladesh, the People's Republic of China, Thailand, and Viet Nam.

Standard Research Protocols. The introductions of tilapia as founder stocks for the development of GIFT and the subsequent regional dissemination of GIFT through DEGITA employed strict protocols for quarantine and assessment of possible environmental impacts. Moreover, the development of GIFT and the evaluation of GIFT through DEGITA used standard protocols for measuring and comparing the growth and survival of farmed tilapia, on a scale never before attempted nationally or regionally. The tagging and communal stocking in diverse test environments, used for the comparisons of strain performance, were largely new to Philippine researchers.[15]

New Applications of Ex-Ante Economic Assessment. DEGITA employed ex-ante economic assessment at the start of adoption of GIFT. This application of ex-ante assessment to aquaculture research was new, not only in the Philippines, but also in aquaculture R&D in general.[16]

Baseline Survey. For the Philippines, as for all national program partners, DEGITA began with a baseline survey of tilapia farming, including its socioeconomic and environmental aspects and the availability of tilapia strains. Prior to the availability of GIFT, GIFT-derived, and other improved tilapia strains, high-quality tilapia seed of known breeding history was unavailable. Farmed Nile tilapia strains were then the descendants of historical introductions from Israel; Singapore; Taipei,China; and Thailand, as well as so-called local strains of unknown ancestry and accidental hybrids of

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[14] PCAMRD. 1990. *Updated Five-Year R&D Plan (1988–1992) of the National Aquatic Resources Research and Development System.* Los Baños, Laguna, Philippines: Philippine Council for Aquatic and Marine Research and Development, Department of Science and Technology.

[15] Eknath, Ambekar, et al. 1993. Genetic Improvement of Farmed Tilapia: The Growth Performance of Eight Strains of *Oreochromis niloticus* Tested in Different Farm Environments. *Aquaculture* 111: 171–188.

[16] PingSun Leung, and Clem Tisdell, eds. 2000. Foreword in the Special Issue: Socioeconomics of Tilapia Culture in Asia. *Aquaculture Economics and Management* 4(1–2).

O. mossambicus. Such unimproved strains and hybrids are still farmed to a limited extent and are usually referred to as "Israel" (historically the most widely farmed Nile tilapia strain of known provenance) and "local" strains.

Superior GIFT Performance. Through DEGITA, the performance of GIFT and Nile tilapia strains commonly farmed in the Philippines was compared on-station and on-farm in diverse environments. During on-farm trials, in ponds and cages, GIFT gave 49% and 54% higher yields, respectively, than the Nile tilapia strains commonly farmed in the Philippines.[17] BFAR recognized that adoption of GIFT would bring better yields and higher profits to farmers and would increase the supply of tilapia as a relatively low-priced fish, thereby improving human nutrition, especially among the poor. Since 1993, NFFTC, as the National Broodstock Center, has disseminated GIFT and GIFT-derived strains to become broodstock nationwide. By the end of 1997, the 13 regional outreach stations of BFAR had received a total of 553,350 GIFT seed as their broodstock (Table A2.3). NFFTC currently disseminates the GET EXCEL tilapia strain, which is GIFT-derived. In 2003, the BFAR regional outreach stations received 663,000 GET EXCEL broodstock, 311 BFAR-affiliated satellite hatcheries received 4.2 million fingerlings, and 405 private hatcheries received 5.9 million fingerlings.[18]

[17] ICLARM. 1998. *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA): Final Report*. Manila.

[18] Sources: FAC and NFFTC. By comparison, in 1998–2002 FAC disseminated more than 400,000 FAST strain broodstock to 51 hatcheries in 8 Regions (15 provinces) and about 65,000 genetically male tilapia broodstock of the Swansea strain.

Table A2.3: Dissemination by the Philippine Bureau of Fisheries and Aquatic Resources of Genetically Improved Farmed Tilapia (GIFT) to Regional Outreach Stations in the Philippines, 1993–1997

Region	Regional Outreach Station	Number of Fingerlings Disseminated					
		1993	1994	1995	1996	1997	Total
I– Ilocos Region	Ilocos Norte	6,600		67,200	20,000	20,000	113,800
II–Cagayan Valley	Isabela	35,000		15,000		40,000	90,000
III–Central Luzon	Zambales		2,100		40,000		42,100
IV–Southern Luzon	Laguna		24,000	20,000			44,000
V–Bicol Region	Camarines Sur		14,850	34,000	30,000		78,850
VI–Western Visayas	Iloilo City		10,000		30,000		40,000
VII–Central Visayas	Cebu City		4,200	3,000	10,000		17,200
VIII–Eastern Visayas	Leyte		22,400				22,400
IX–Western Mindanao	Zamboanga		13,200		5,000		18,200
X–Northern Mindanao	Agusan del Norte		12,000				12,000
XI–Eastern Mindanao	Davao		14,000	10,000		20,000	44,000
XII–Central Mindanao	Cotabato City		10,000		8,000		18,000
Cordillera Autonomous Region	Benguet		12,800				12,800
Total		**41,600**	**139,550**	**149,200**	**143,000**	**80,000**	**553,350**

Source: Eknath, Ambekar, and Belen Acosta. 1998. *Genetic Improvement of Farmed Tilapias Project: Final Report (1988–1997), Part 1*. Manila: ICLARM.

Commercialization of GIFT. In 1996, CLSU, the Department of Agriculture (through BFAR), and ICLARM signed a 25-year collaborative research agreement to continue applied genetics research in support of tilapia farming. The core facilities in which GIFT had been developed on the CLSU campus were renamed under this agreement the Center for Applied Fish Breeding and Genetics. The same partners also jointly established the Genetic Improvement of Farmed Tilapia Foundation International Incorporated (GFII), a nonstock, nonprofit corporation, incorporated in the Philippines, as

the main mechanism for the continuation of GIFT R&D in the Philippines.[19] Dissemination of GIFT to small numbers of GIFT-accredited private hatcheries actually started in 1995 and continued thereafter from GFII. By the end of 2001, GFII had disseminated 522,700 GIFT broodstock to GIFT-accredited private hatcheries.[20] However, accreditation required high standards of broodstock husbandry and hatchery operation, up-front licensing fees, and monthly contributions to GFII's ongoing R&D. Few hatchery operators were able or willing to meet these conditions. In 1995, accreditation was given to only seven hatcheries in Regions III, IV, and V. In 1999, to maintain its operations, GFII entered into partnership with Genomar ASA (Oslo, Norway), which took over the distribution of new GIFT generations in the Philippines, renamed as Genomar Supreme Tilapia™.[21]

INTERNATIONAL NETWORK ON GENETICS IN AQUACULTURE (INGA)

INGA was founded in 1993, with ICLARM as member-coordinator, through funds from the United Nations Development Programme (UNDP).[22] Joining INGA was entirely consistent with and supportive of Philippine national needs and priorities and facilitated the sharing of Philippine research in aquaculture genetics with INGA members in the Asia-Pacific and other regions.[23]

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[19] In 1998**,** by agreement of all partners in the Center for Applied Fish Breeding and Genetics, GFII occupied 8 hectares of the core facilities used to develop GIFT and employed most of the highly trained team of Philippine staff that had developed and disseminated GIFT.

[20] (i) GFII, (ii) Eknath, Ambekar, and Belen Acosta. 1998. *Genetic Improvement of Farmed Tilapias Project: Final Report (1988-1997) Part I*. Manila: ICLARM.

[21] By agreement with GFII, Genomar ASA acquired the rights to commercialization of GIFT from subsequent generations of selective breeding. GFII became contracted to Genomar ASA to perform, on its behalf, further selective breeding on the GIFT strain to produce the Genomar Supreme Tilapia, with GFII also distributing Genomar Supreme Tilapia fingerlings from its own hatchery.

[22] ICLARM.1993. *Summary of Proceedings of the Workshop on Networking for Genetics in Aquaculture*. Manila. Available: http//: www.worldfish.org/inga/

[23] For example: Camacho, Arsenio, Tereso Abella, and Melchor Tayamen. 2001. Fish Genetics Research and Development in the Philippines. In Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics in Aquaculture, edited by Modadugu Gupta and Belen Acosta. *ICLARM Conference Proceedings* 64. p. 71–76. Manila.

OUTCOMES AND IMPACTS

Gene Banking. From the African wild and Asian farmed tilapia strains assembled for development of GIFT and from subsequent tilapia breeding programs, the Philippines has acquired unique, diverse, and highly valuable collections of Nile tilapia genetic resources. Prior to the development of GIFT, there was no systematic gene banking of farmed fish genetic resources in the Philippines. During the development of GIFT, technology and training for tilapia gene banking were introduced, combining cryopreserved sperm and live broodstock collections.[24] NFFTC currently maintains a tilapia gene bank of national, regional, and international importance.

Changes in Tilapia Hatchery Practices. The development and dissemination of GIFT and GIFT-derived strains have given tilapia seed producers wider access to high-quality broodstock. Hatchery operators have responded by more careful broodstock management, with regular replacement of spawners, usually after 18–24 months. Availability of the new tilapia strains has made tilapia seed producers more aware of and willing to try other new technology. For example, the production of SRT seed is steadily increasing. In 2003, according to the survey of 136 hatcheries conducted for this study, SRT comprised 55.7% of the total sales volume of 800.9 million seed.

Changes in Tilapia Farming Practices. The fast growth of GIFT, GIFT-derived, and other genetically improved tilapia has enabled farmers to harvest fish from intensively managed ponds after only 3–4 months, compared with the 6–7 month production cycles that were typical of unimproved strains and less intensive husbandry. This has made possible two or three production cycles in a year and higher fish harvests, particularly for tilapia farmers with abundant water supply. In central Luzon, for example, the average yield of intensively managed tilapia ponds is about 8 t per hectare (ha) per crop cycle, or 16 t/ha for a two-crop cycle. In southern Luzon, a 10 x 10 x 10 meter cage yields 3 t/crop cycle, or 6 t/year for two crop cycles.[25]

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[24] Cryopreservation technology was introduced to NTFFC and FAC during the GIFT R&D, from the Institute for Aquaculture, University of Stirling, United Kingdom. By 1998, the GIFT gene bank at NFFTC included cryopreserved sperm and live broodstock from the African and Asian founder stocks collected, the base population for selective breeding of GIFT strains, and the selectively bred GIFT strains then available. In 2003, NFFTC's cryopreservation facility was upgraded through investment of more than P1 million of government funds.

[25] ADB. 2004. *Special Evaluation Study on Small-Scale Freshwater Rural Aquaculture Development for Poverty Reduction*. Manila.

Partnerships and Linkages. As the host country in which GIFT were developed and from which they were disseminated, the Philippines benefited from the skills and experience contributed by its international and foreign national partner institutes.[26] Through INGA membership, the Philippines gained access to a wide range of aquaculture genetics information as well as to outlets for sharing and publishing its own research results. Regional and international linkages acquired through INGA have enabled the Philippines to participate in and benefit from a wide range of collaborative genetic research, training, formulation of protocols and agreements, and workshops. These have enhanced the capacity of Philippine national institutions, especially through training in quantitative genetics and in the design of fish breeding programs provided by staff of advanced scientific institutions.[27] Philippine R&D experience is exchanged with other INGA members through regional workshops and publications.

The advent of GIFT and GIFT-derived strains of Nile tilapia was the major catalyst for increasing the diversity and importance of public-private partnerships in tilapia breeding and seed dissemination in the Philippines. The longest standing partnerships are those among NFFTC, its regional and provincial stations, and their hatchery operator and farmer clients. Other partnerships are evolving among the GFII and its public and private sector partners and clients, and between FAC and users of its tilapia breeds. These public-private partnerships have become the subject of intensive research.[28]

Increased Choice of Tilapia Strains for Farmers. Prior to the development and dissemination of GIFT and GIFT-derived strains, most tilapia farmers and researchers were restricted to using Nile tilapia strains or hybrids with poorly documented breeding histories and unpredictable performance. There is now a wider choice of well-documented and improved Nile tilapia strains for production, breeding programs, and further research, principally: Genomar Supreme Tilapia™, which are GIFT strains; the GET EXCEL strain, which is GIFT-derived; and the FAST strain. In the hatchery survey undertaken for this study, respondents were asked to give scores of

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[26] During the development and dissemination of GIFT, the Philippine national partner institutes became members of an international research team, with fish geneticists from the Norwegian Institute of Aquaculture Research and ICLARM scientists, and with their many colleagues and contacts in aquaculture genetics around the world.

[27] INGA has 12 advanced scientific institutions as members in Asia, Australia, Europe, Israel, and the United States.

[28] The International Development Research Centre of Canada funded a major study in this area. See: Final Workshop on Public-Private Partnerships in Tilapia Genetics and Dissemination of Research Outputs: Philippine Experience, 21–23 January 2004, Tagaytay City, Philippines. CD-ROM. Penang: WorldFish Center.

1–10 for perceived performance characteristics (growth, survival, fecundity, and color) of their chosen Nile tilapia strains.[29] Statistically significant mean differences ($p<0.05$) in perceived growth were discernable in several cases: (i) Genomar Supreme Tilapia™ and GIFT (7.93) versus the unimproved and formerly widely farmed Israel strain (6.15); (ii) Genomar Supreme Tilapia™ and GIFT (7.93) versus tilapia strains of unknown provenance (6.10); (iii) the GIFT-derived GET EXCEL strain (7.76) versus Israel strain (6.15); and (iv) GET EXCEL (7.76) versus strains of unknown provenance (6.10).

Impacts on Tilapia Production. The dissemination of GIFT and GIFT-derived strains through a broad network of public and private tilapia hatcheries in the Philippines has undoubtedly had a large and favorable impact on tilapia production. However, the contributions of different tilapia strains cannot be estimated directly from production statistics. The Fisheries Statistics Division of the Bureau of Agricultural Statistics presents farmed tilapia production as a single commodity, not disaggregated by species or strain.

In the absence of disaggregated statistics on farmed tilapia, a survey of 136 private and government tilapia hatcheries, representative of tilapia seed production across the country, was undertaken for this study in February–March 2004. The contributions of different tilapia strains to national production of tilapia seed can be used as indicators of their relative contributions to farmed tilapia production. The Genomar Supreme Tilapia™, which is a GIFT strain, and the GIFT-derived GET EXCEL strain together contributed 67.6% of the total tilapia seed produced (922.5 million) in 2003 by the hatcheries surveyed (Table A2.4). From the survey, private hatcheries were responsible for 81.5% of the total GET EXCEL production (421.4 million seed) in 2003. This reflects the achievement of the Government's nationwide dissemination of GET EXCEL tilapia program, which has a budget of P5.7 million. Contributions of nonGIFT strains (neither GIFT nor GIFT-derived) to total tilapia seed production were: FAST (20.3%), GMT (6.4%), local strains of unknown provenance (3.8%), and the formerly widely farmed Israel strain (1.9%).

The GIFT-derived GET EXCEL strain was the only improved tilapia strain for which seed was produced in all tilapia farming regions, by virtue of its nationwide distribution through NFFTC channels. Despite variations in the production of Nile tilapia strains across regions, the survey indicated seed producers' preferences for

[29] The scores obtained from the survey represent perceived characteristics of tilapia strains, in the absence of actual measurement and analysis of their performance traits in respondents' hatcheries.

improved strains (GET EXCEL, GST, and FAST) over GMT and unimproved strains (local and Israel). In 2003, central Luzon, where GIFT originated, accounted for 70.8% of national tilapia seed production, with GIFT and GIFT-derived strains dominant, followed by FAST. There is considerable scope for future growth of tilapia seed production and farming in Mindanao, for example in the provinces of Sultan Kudarat and South Cotabato. This is a potential growth area outside the traditional tilapia farming areas.

Table A2.4: Production of Different Strains of Nile Tilapia Fry and Fingerlings in 2003, Philippines (million fry and fingerlings, with percentage shares of total production)

Strain and Affinity to GIFT	Central Luzon	Southern Luzon	Northern Luzon	Bicol	SOCCSK-SARGEN[a]	Total Philippines
GET EXCEL (GIFT-derived)	322.5 (49.4%)	40.7 (30.5%)	33.6 (84.1%)	7.1 (62.0%)	17.5 (20.7%)	421.4 (45.7%)
Genomar Supreme Tilapia™ (GIFT)	187.9 (28.8%)	—[b]	—	—[b]	13.7[c] (16.2%)	201.6 (21.9%)
FAST (nonGIFT)	83.3 (12.9%)	64.7 (48.5%)	6.2 (15.5%)	—	32.8 (38.8%)	187.0 (20.3%)
GMT (nonGIFT)	55.5 (8.5%)	-	0.1 (0.4%)	0.7 (6.2%)	3.0 (3.5%)	59.3 (6.4%)
Local (nonGIFT)	4.0 (0.6%)	28.0 (21.0%)	—	3.6 (31.7%)	—	35.6 (3.8%)
Israel (nonGIFT)	—	—	—	—	17.6 (20.8)	17.6 (1.9)
All strains	653.2 (70.8%)	133.4 (14.5%)	39.9 (4.3%)	11.4 (1.2%)	84.6 (9.2%)	922.5 (100.0%)

— = not available, GIFT = genetically improved farmed tilapia, GMT = genetically male tilapia.

[a] The region in Mindanao comprising the provinces of South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos.

[b] The Genomar Supreme Tilapia strain was also produced in southern Luzon and Bicol, but the respondents did not disclose their production data.

[c] Hatcheries in the region in Mindanao comprising the provinces of South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos used earlier generations of the GIFT strain.

Source: Impact Evaluation Study, survey of Philippine hatcheries.

Based on the hatchery survey, total tilapia seed sales expanded from 693.2 million in 2001 to 800.9 million in 2003, while corresponding gross sales value increased from P207.8 million to P249.4 million. The GIFT and GIFT-derived strains accounted for 536 million seed (66.9%) of the total seed sold in 2003, higher than in 2001 (440.9 million seed, share of 63.6%). This was due largely to the wider dissemination of the GIFT-derived GET EXCEL strain. Over this period, the market share of GET EXCEL increased from 44.5% to 48.4%, whereas that for Genomar Supreme Tilapia™ was about the same (19.1% and 18.5%, respectively).

Impacts on Employment. The widespread dissemination and adoption of GIFT and GIFT-derived strains have contributed to the expansion of tilapia farming, which has provided opportunities for employment. Tilapia farming provides employment in pond excavation, cage and net making, fish feeding, fish harvesting, sorting/grading, marketing, transport, and miscellaneous activities. At least 280,000 people, including their families, directly and indirectly benefit from employment generated by freshwater tilapia farming alone (footnote 25). This does not include additional full-time, part-time, and seasonal labor required by allied industries, such as tilapia feed processing; supply of fertilizers, tilapia, seed and other inputs; and their respective processing and distribution.

Based on the hatchery survey, employment at hatcheries in 2003 was on average 3.4 persons/ha. Men comprised 84% of the workforce, and women, 16%. Given the total area of approximately 1,148 ha,[30] tilapia hatcheries directly employed about 3,900 persons in 2003. About two thirds of these persons worked in hatcheries that produced GIFT and GIFT-derived seed. FAST seed hatcheries employed 21% of the hatchery workforce, and GMT, 6%. The others were in hatcheries that produced local (3%) and Israel (2%) strains.[31]

Impacts on Income from Tilapia Farming. Tilapia pond and cage farming can generate highly attractive net returns.[32] In 2002, the average net return per hectare per 4-month cycle for farming tilapia

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[30] Based on an average of 1.9 ha per hatchery and a national total of 604 hatcheries.

[31] In general, the average daily wage of manual laborers in Philippine tilapia hatcheries was P140 in 2003, but certain benefits were provided, such as free meals/snacks, board and lodging, bonuses, and rice ration. Some hatcheries did not give salaries to manual laborers, but adopted profit-sharing schemes or provided commissions as a compensation scheme (about 25% of farmer responses). Other hatchery workers received the following monthly salaries: (i) technical staff (P6,134); (ii) sales staff (P8,500); and (iii) supervisory/managerial staff (P16,125).

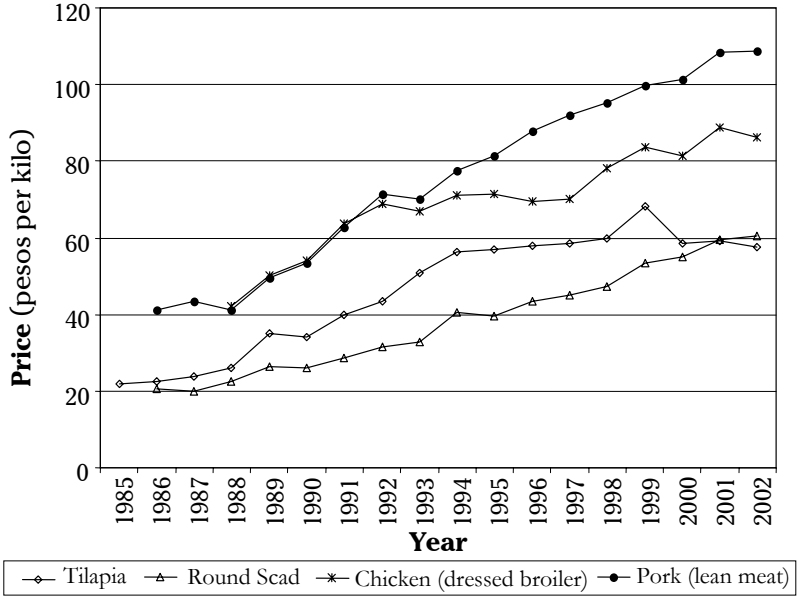
[32] Net returns are defined as total revenues from sales of tilapia less total production costs and marketing expenses. Production costs include both cash costs and non-cash costs, where non-cash costs refer to depreciation and imputed family labor.

(in this case, GIFT and GIFT-derived strains) in ponds was P101,188, or P202,376 at two crop cycles per year (footnote 25). The average harvest from central Luzon ponds was 8.5 t/ha per crop cycle, with 85% fish survival from stocking to harvest. The corresponding average net return from a 1,000 cubic meter tilapia cage in Taal Lake was P21,119 per crop cycle. The average harvest per cage was 3 t per cycle at two cycles per year, with 70% fish survival. A farmer with five cages, who harvested tilapia twice in 1 year, earned P211,190. These returns make tilapia farming an attractive livelihood, particularly for those who have access to natural resources (water and land), financial capital, technical advice, production inputs (tilapia fry/fingerlings, feeds, and fertilizers), and markets.

Hatchery respondents indicated profits from their operations, but perceived a decline in profitability ($p<0.05$) during 2001–2003 due to increasing competition, rising costs of producing tilapia seed, and losses due to uncollected receivables. Most hatchery operators (68%), nonetheless, were optimistic about their future and planned to continue their hatchery operations. About 30% intended to expand their operations, whereas only 2% expected a reduction in future operations due to uncertain prospects and financial losses. Optimism for the future increased with hatchery size. Operators of large hatcheries anticipated higher profitability 5 years from now ($p<0.05$), whereas smaller hatcheries did not expect their profits to be significantly different from 2003 levels. Across regions, hatcheries in central Luzon had the most optimistic perception of the future in this regard.

Impacts on Human Nutrition. Tilapia farming in the Philippines contributes significantly to human nutrition, especially among the poor, because tilapia is a relatively low-priced fish. In 1979–1988, before the development of GIFT and other genetically improved tilapia, average national tilapia consumption was 0.66 kg per capita per year. During 1989–1997, this rose to 1.61 kg per capita per year, an increase of 144%, with higher consumption in the primary tilapia farming regions. Field surveys (1995–1996) reported annual per capita tilapia consumption of 39.5 kg by rural tilapia producers, compared with 15.9 kg by rural nonproducers and 5.8 kg for urban nonproducers. Based on the survey conducted for this study, about 68% of the farmed tilapia consumed in the Philippines in 2003 was GIFT or GIFT-derived. Tilapia has been a more affordable source of protein than pork or chicken (Figure A2.2). The round scad (*Decapterus* spp., locally called *galunggong*), a marine fish, has traditionally been the fish most available to and affordable by poor consumers. Its supply is threatened as marine fisheries decline.

Figure A2.2: Nominal Retail Prices of Tilapia, Round Scad, Chicken, and Pork in the Philippines, 1985–2002



Source: Bureau of Agricultural Statistics.

Tilapia has a demand elasticity that ranges from 1.24 for the lowest-income group to 0.99 for high-income groups. This implies that lower-income groups tend to respond more to price changes.[33] For example, a 10% decrease in tilapia prices will increase tilapia consumption by lower income groups by 12.4%. Thus, the poor stand to benefit from lower tilapia prices.

Impacts on Policy. In 1990, parallel to the early development of GIFT, PCAMRD initiated a 3-year National Tilapia Production Program, emphasizing genetic improvement and dissemination of improved breeds (footnote 14). During 1993–1998, Philippine national policies on fisheries development were set by the Medium Term Fisheries Management and Development Program, which emphasized freshwater aquaculture to increase fish production, with genetic improvement of tilapia as a means to this end.[34] The

[33] Source: Analysis of Fish Demand in the Philippines. Study conducted by Dr. Yolanda Garcia, Dr. Madan Dey, and Ms. Sheryl Narvaez as part of the Philippine Component of Asian Development Bank TA 5945-REG *Study on Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia*, for $1.1 million, approved on 17 October 2000.

[34] Department of Agriculture. 1993. *Medium Term Fisheries Management and Development Program: a Component of the Medium Term Agricultural Development Program (MTADP), 1993–1998*. Quezon City, Philippines: Department of Agriculture.

development of GIFT, GIFT-derived, and other genetically improved tilapia has undoubtedly helped the implementation of this policy for expansion of freshwater aquaculture, although government support for further application of genetics in aquaculture has not matched the contributions of aquaculture to national fish supply.[35] Policies to harmonize public and private sector relationships in Philippine tilapia seed supply and to foster increased private sector R&D for tilapia genetic improvement are not yet developed. To date, there is insufficient national support for expanding and duplicating gene banks (for security reasons) of tilapia and other farmed fish, and for coordinated gene banking within and between the public and private sectors.

Impacts on Biodiversity and the Environment. Introductions of Nile tilapia for the development of GIFT and the subsequent nationwide dissemination of GIFT and GIFT-derived strains are unlikely to have caused any significant impacts on the natural environment and biodiversity, additional to those already made by prior tilapia introductions. The introductions of Mozambique tilapia (*O. mossambicus*) and Nile tilapia (*O. niloticus*) to the Philippines in 1950 and the 1970s, respectively, resulted in their establishment as alien species in open waters. *O. mossambicus* has been problematic in the Philippines and in many other countries outside its natural range; *O. niloticus* much less so.[36] The biodiversity and environmental quality of inland waters in the Philippines have been seriously degraded by many factors, such as overfishing, pollution, siltation, and water diversion, as well as alien species introductions and aquaculture. The impacts of Nile tilapia in Philippine lakes are difficult to assess because of the many factors that have contributed to degradation of the lakes. However, as emphasized in a study undertaken during the development of GIFT, precaution and prior

[35] In 2002, according to BFAR statistics, the Government's total budget for fisheries and aquaculture research, development, and extension was P296 million, inclusive of P73 million external support. This budget represented about 0.8% of the total value of the country's 2002 aquaculture production. In 2002, the Government allocated a research, development, and extension budget of only P20 million to the freshwater sector, with P8 million for tilapia genetics. Source: Philippine Council for Aquatic and Marine Research and Development, Los Baños, Laguna, Philippines. *2003 Report*, cited by FAC, CLSU, Science City of Muñoz, Nueva Ecija, Philippines.

[36] Pullin, Roger, Maria-Lourdes Palomares, Christine Casal, Madan Dey, and Daniel Pauly.1997. Environmental Impacts of Tilapia. In *Tilapia Aquaculture. Proceedings of the Fourth International Symposium on Tilapia in Aquaculture.* Volume 2, edited by Kevin Fitzsimmons. Ithaca, New York: Northeast Regional Agricultural Engineering Service Cooperative Extension. p. 554–570.

appraisal of possible impacts of tilapia dissemination and escapes into new water bodies are always advisable.[37]

Introductions of Nile tilapia from Africa for the development of GIFT were made under the highly precautionary policies of ICLARM. The founder stocks introduced directly from Africa were subjected to the strict quarantine for 3–7 months in a completely isolated facility at NFFTC, established in consultation with the BFAR Fish Health Unit and the International Development Research Centre of Canada. As a member of INGA, the Philippines has followed INGA's voluntary protocols for responsible movement of fish germplasm.[38] Philippine national regulations on fish quarantine and biosafety are also extensive. However, the capacity of national agencies such as BFAR to enforce them remains limited. This puts at risk not only wild biodiversity and the natural environment but also the biodiversity and genetic resources of Philippine aquaculture. Many who introduce and distribute alien species and farmed aquatic organisms, including aquarists, fish farmers, and some researchers, fail to adhere to regulations. A survey during DEGITA (footnote 1[ii]) found that 84% of Philippine tilapia farmers believed that tilapia do not displace native fish species (footnote 17). A major and long-term effort is still required to educate public and private actors toward more responsible behavior with respect to fish movements and quarantine.

Impacts in Stocking Open Waters and Disaster Relief. Since the 1980s, BFAR has released millions of Nile tilapia seed annually into open waters to improve the inland fisheries of communal waters or as contributions to public relief measures following severe typhoons and other disasters. GIFT-derived strains have largely taken over these roles from those used before the development of GIFT.[39]

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[37] Bentsen, Hans, Trygve Berg, and Peter Johan Schei. 1992. Environmental Effects of Release and Dissemination of Improved Nile Tilapia. Report prepared by the Agricultural University of Norway for UNDP, Division of Global and Interregional Programmes. 10 p.

[38] Source: http://www.worldfishcenter.org/inga

[39] In 2001, 2002, and 2003, using the GIFT-derived GET 2000 strain, BFAR stocked Philippine communal waters with 3.1, 13.8, and 82.0 million tilapia seed, and dispersed 7.5, 4.2, and 1.2 million additional seed, respectively, for disaster relief after typhoons. Source: Tilapia annual production reports of the Bureau of Fisheries and Aquatic Resources, National Freshwater Fisheries Technology Resource Center, Science City of Muñoz, Nueva Ecija, Philippines.

OVERALL ASSESSMENT

The most significant outcome of GIFT development and dissemination in the Philippines has been the successful application of genetics in the breeding of new and better performing strains of farmed tilapia and their distribution to farmers. Socioeconomic impacts are evident in the extent of use of GIFT and GIFT-derived strains, which now comprise about 68% of the tilapia seed produced in hatcheries. They are further seen in the increasing availability of an affordable source of protein to consumers as well as in the generation of employment and incomes for tilapia farmers, workers, and various market intermediaries. Without the development and dissemination of GIFT, tilapia genetics research and breeding programs in the Philippines and their contributions to increasing tilapia production would have been delayed, probably by at least a decade. Instead, farmed tilapia is now recognized as the most important food fish for poor consumers in the Philippines, soon to replace the round scad or *galunggong*.[40]

The notable institutional impacts have been in the form of national research capacity, the GIFT-based Philippine national tilapia breeding program, the existence of collaborative mechanisms for bringing together tilapia stakeholders (Tilapia Science Center, Tilapia Congresses, etc.), and related public-private sector partnerships. The impacts and the sustainability of these rapidly evolving institutional arrangements will depend primarily on the prospects for strong, long-term growth of tilapia farming. These prospects are good, as indicated by government endorsement of farmed tilapia as a major contributor to the national economy and as a fish of special significance for poor consumers. A further indication of the prominent international position held by the Philippines in tilapia farming and associated R&D is the Philippines' hosting of the Sixth International Symposium on Tilapia in Aquaculture in Manila, 12–16 September 2004.

Genetic improvement of tilapia appears prominently in the programs emerging under these institutional arrangements, although its success will depend on how farmers cope with new technology

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[40] In the Philippine Fisheries Industry Plan for 1999–2004, aquaculture is identified as the "*best bet*" and tilapia identified as the most promising farmed fish commodity. BFAR.1999. *The Philippine Fisheries Industry Plan, 1991–2004*. Quezon City, Philippines: Bureau of Fisheries and Aquatic Resources, Department of Agriculture. In 2003, President Gloria Macapagal Arroyo stated that "*galunggong will soon be replaced by tilapia as the food of the masses*." Villanueva, Marichu. 2003. Gloria Pushes Tilapia as Pinoy Staple. *The Philippine Star*, 4 November 2003. p. 1 and 8.

and on the coverage and quality of extension services.[41] Aquaculture extension services in the Philippines have traditionally been the responsibility of government and the public sector, mainly through BFAR and state universities and colleges. However, there are strong indications that farmer-to-farmer networking and technical advisory services from suppliers of fish seed, feed, agrochemicals, and equipment have recently become more important and effective than the traditional extension channels (footnote 25). Philippine tilapia farming has changed dramatically through genetics-based technologies and has entered a phase of rapid growth with increasing private sector participation in R&D and in the provision of technical advice.[42] Accredited private hatchery operators who receive improved tilapia broodstock are required to undergo training on the genetic aspects of broodstock management and hatchery operation. These developments have resulted largely from the development and dissemination of GIFT and GIFT-derived strains.

Sustainability of Small-Scale Tilapia Farming and Seed Production. The recent dynamic growth of tilapia farming in the Philippines, catalyzed largely by genetic improvement, has brought not only opportunities but also challenges. As tilapia production and domestic and export markets expand, sustaining benefits to small-scale producers and poor consumers of tilapia will be a major challenge. The future economic viability of small-scale tilapia farms seems much more likely than that of small-scale tilapia seed producers. As long as affordable seed supplies are available, small-scale tilapia farms should remain profitable enterprises, supplying fish to rural and urban markets. Small-scale tilapia farming should be able to coexist with larger corporate farms and to prosper, provided that future tilapia breeding does not lead to situations that restrict access to tilapia seed supply because of pricing and husbandry requirements beyond the reach of poor farmers. To date, there is no evidence that the GIFT and GIFT-derived strains have led to such situations. Rather, they are increasing tilapia production from a range of farming systems and expanding fish supply to a wide range of consumers, including the poor. Nevertheless, worldwide trends indicate that fish seed production becomes increasingly separate from growout

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[41] Sevilleja, Ruben. 2000. Adoption and Economics of Tilapia Farming Technology in the Philippines. In *Microbehavior and Macroresults. Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade.* 10–14 July 2000. Corvallis, Oregon, USA.
Available: http://oregonstate.edu/Dept/IIFET/html/publications.html

[42] The Genomar-GFII partnership is an example where the private sector is directly involved in R&D for genetic improvement of tilapia. This marked the formal entry of a foreign private commercial company in genetic improvement and dissemination of improved tilapia in the Philippines.

operations. Seed production in the Philippines has benefited from economies of scale with the development of larger hatcheries and will likely become concentrated into fewer and larger corporate enterprises.

Risks to Maintaining and Increasing Benefits from Tilapia Genetic Improvement. There are risks to maintaining and increasing the benefits that tilapia genetic improvement has brought to the Philippines. Most of these risks are common to all farming and food production; for example, climatic uncertainties and changing economic circumstances with respect to the cost of inputs for farming and the availability and prices of competitive products. However, tilapia breeding and farming are especially vulnerable to diseases and parasitic infestations through ineffective quarantine, irresponsible fish introductions, and bad husbandry. Addressing these multiple and interrelated risks requires strong policies and support to sustain the institutional advances that have come with tilapia genetic improvement. In particular, there are policy gaps to be filled and needs for increased support in the areas of biosafety, gene banking, and seed certification.

APPENDIX 3

Impacts of Genetically Improved Farmed Tilapia in Bangladesh

TILAPIA FARMING: RELEVANCE OF GENETIC IMPROVEMENT RESEARCH

This appendix reviews impacts in Bangladesh of genetically improved farmed tilapia (GIFT), a product of research and development (R&D) efforts supported by technical assistance financed by the Asian Development Bank (ADB) and others.[1] The Mozambique tilapia (*Oreochromis mossambicus*), introduced to Bangladesh from Thailand in 1954, was not widely accepted for farming because it matured early and bred prolifically, leading to overcrowded ponds. In 1974, the Chitralada strain of Nile tilapia (*O. niloticus*), a far superior farmed tilapia, was introduced to Bangladesh from Thailand. However, most farmers continued to farm carps; tilapia farming was slow to develop. The Bangladesh Fisheries Research Institute (BFRI) reintroduced Nile tilapia and red tilapia (hybrids of *Oreochromis* species) from Thailand in 1987 and 1988, and began to develop low-cost tilapia farming systems.

GIFT were introduced to BFRI in 1994 under the Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA, footnote 1[ii]), and their performance was found to be significantly superior to that of tilapia previously available. Subsequent attempts to disseminate GIFT to tilapia seed producers and farmers have been constrained by resource limitations, lack of hatchery-produced seed, and by the continuing national focus on the carp polyculture that has traditionally dominated inland aquaculture in Bangladesh.[2] In 2002, total fish production in Bangladesh reached 2.3 million tons (t): 37% from freshwater aquaculture, 33% from inland fisheries, 26% from marine fisheries, and 4% from coastal

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1 (i)TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988. This R&D effort was also supported by the United Nations Development Programme and research partner institutes.
(ii)TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia*, for $600,000, approved on 14 December 1993.

2 ADB. 2004. *Special Evaluation Study on Small-Scale Freshwater Rural Aquaculture Development for Poverty Reduction.* Manila.

aquaculture.[3] During 1986–2002, annual freshwater aquaculture production rose from 123,800 to 850,000 t, involving more than 900,000 households and more than 400,000 hectares (ha) of ponds and ditches. Polycultures of Indian and Chinese carp, along with small indigenous species, comprised 85% of total aquaculture production. Monocultures, mainly of catfish (*Pangasius hypophthlamus*, locally called *pangas*) and tilapia, made up only 3% of total aquaculture production. Accurate statistics for tilapia production are not yet available. Small-scale tilapia farming, however, is probably practiced more widely than available statistics suggest. Fish harvests containing tilapia, from small ponds and ricefields, are often used largely for household consumption, particularly in such regions as the northwest, the poorest region in the country.[4] Interest in tilapia farming is growing primarily because of its successes in other Asian countries and increasing consumer acceptance. In addition to the efforts of BFRI and the public sector, private sector hatcheries are increasing the supply of high-quality tilapia seed, including GIFT.[5]

ENABLING FACTORS AND CONSTRAINTS

BFRI has a mandate to carry out basic and adaptive research on living aquatic resources and to coordinate fisheries research activities in Bangladesh. It maintains a large Freshwater Station in Mymensingh, adjacent to the Bangladesh Agricultural University. Since 1984, with substantial external support, BFRI has conducted research on fish seed production and husbandry, including genetics, and has trained aquaculture extension workers and farmers.[6] The profile of aquaculture genetics in Bangladesh was raised in part by BFRI participation in DEGITA (1994–1997, footnote 1[ii]) and more

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[3] Department of Fisheries. 2003. *The Future for Fisheries: Findings and Recommendations from the Fisheries Sector Review and Future Development Study*. Dhaka.

[4] Barman, Benoy, David Little, and Peter Edwards. 2001. Small-Scale Fish Culture in Northwest Bangladesh: a Participatory Appraisal Focusing on the Role of Tilapia. In *Rural Aquaculture*, edited by Peter Edwards, David C. Little, and Harvey Demaine. Wallingford, UK: CABI Publishing. p. 227–244.

[5] Seed means fry and fingerlings. Tilapia seed are produced from broodstock in hatcheries and raised there to become fry and fingerlings, although sometimes the fry to fingerling growth phase is accomplished in separate nurseries. The farming of fish seed to harvestable size is called growout.

[6] The funding agencies for this have included, among others, ADB, the Australian Center for International Agricultural Research, the Department for International Development of the United Kingdom, the International Development Research Centre of Canada, and the United States Agency for International Development.

recently in ADB-financed carp genetic improvement (1997–2001).[7] BFRI maintains breeding nuclei of GIFT and red tilapia, and has undertaken selective breeding of GIFT through five generations since 1999, thereby developing a superior strain renamed the BFRI Super Strain of GIFT. Ten scientists are currently involved in aquaculture genetics, but expenditure on tilapia research in 2003 comprised only 5% of that on all aquaculture research.[8]

In 1993, Bangladesh, with BFRI as its leading institute, became a founding member of the International Network on Genetics in Aquaculture (INGA), enabling acquisition of fish germplasm from other countries and wider international R&D partnerships.[9] Through INGA, in addition to GIFT from the Philippines, Bangladesh received common carp (*Cyprinus carpio*) germplasm from Viet Nam and silver barb (*Barbodes gonionotus*) germplasm from Indonesia and Thailand for stock improvement.

The limitations of aquaculture statistics in Bangladesh currently preclude quantification of the contributions of GIFT to tilapia production. There is scattered evidence for use of GIFT. A survey conducted jointly in 2003 by the WorldFish Center and BFRI in the central and southeastern regions found that all of 17 fish seed producer respondents were selling GIFT seed along with the seed of carps and other species.[10] Most of these seed producers had obtained their GIFT broodstock from BFRI. Some had attempted to develop their own broodstock thereafter, but were experiencing difficulties due to inbreeding and scarcity of replacements. The same survey found that BFRI had supplied GIFT seed to seven of ten respondents farming GIFT. Their other sources of GIFT seed were private hatcheries in Bangladesh, the Department of Fisheries, and imports from Thailand. Although BFRI has had a pivotal role in making GIFT available to hatcheries and farmers, dissemination of GIFT has been limited. Expansion of tilapia farming in Bangladesh still faces many constraints, including limited technical support and information on

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[7] TA 5711-REG: *Genetic Improvement of Carp Species in Asia*, for $1.3 million, approved on 12 December 1996.

[8] Source: response from the Bangladesh Fisheries Research Institute, Mymensingh to a questionnaire on GIFT use, sent from the WorldFish Center, Penang, Malaysia, in its capacity as Member-Coordinator of the International Network on Genetics in Aquaculture.

[9] Hussain, M.G., and M. A. Mazid. 2001. Aquaculture Genetics Research in Bangladesh. In *Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics in Aquaculture*, edited by Modadugu Gupta and Belen Acosta. Penang: WorldFish Center. p. 7–14.

[10] WorldFish Center, Bangladesh, and Bangladesh Fisheries Research Institute. 2004. *Status of Tilapia/GIFT Seed and Growout Production in Hatchery-Nursery and Farm-Based System in Bangladesh.* Penang.

tilapia farming methods, poor tilapia seed quality and availability, continuing high seed prices, and lack of access among farmers to financial capital.[11]

OUTCOMES AND IMPACTS

Better Tilapia for Research and Production. On-farm pond trials conducted by BFRI in six agroclimatic zones of Bangladesh in 1995–1996 indicated that GIFT were on average 58% superior to locally available Nile tilapia in terms of growth.[12] In 6-month trials, GIFT in ponds gave an average yield of 1,593 kilograms (kg)/ha compared with 896 kg/ha from local Nile tilapia strains (footnote 12). In subsequent on-farm trials in ponds, conducted in 2003 (footnote 8), GIFT selectively bred by BFRI were fed with rice bran and gave a higher average yield (3,750 kg/ha) than nonselected GIFT (2,750 kg/ha) after 5 months.

R&D Methods. GIFT R&D methods, particularly those used during DEGITA and shared through INGA membership, have strengthened the capacity of BFRI and other national research teams in quantitative genetics and in integrating biological and social assessments in impact analysis. Through DEGITA and INGA, 6 scientists and 20 hatchery managers received technical training in aquaculture genetics and broodstock management, respectively. GIFT R&D methods have facilitated the development of fish breeding programs in Bangladesh, and these methods are applied not only in further selective breeding of GIFT but also to silver barb, catla (*Catla catla*), and rohu (*Labeo rohita*).[13]

Livelihoods and Nutrition. Tilapia has great potential in Bangladesh, in both mono- and polyculture, as an alternative and additional species of farmed fish. The total number of fishponds in the country probably exceeds 5 million if small homestead fishponds

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[11] (i) Amrit, Bart, Mohammad Haque, and Mohammad Wahab. 2004. Tilapia Culture in Bangladesh: Technological Constraints; and (ii) Ganesh, Shivakoti, and Jiban Majumder. 2004. Constraints on Tilapia Production in Bangladesh: Looking from a Socioeconomic Perspective. Papers presented at the Workshop on Tilapia Culture in Bangladesh: Constraints and Potentials, 4–5 April 2004, Mohakhali, Dhaka. Mymensingh: Bangladesh Fisheries Research Institute.

[12] Dey, Madan, Ambekar Eknath, Li Sifa, M.G. Hussain, Tran Mai Thien, Nguyen van Hao, Simeona Aypa, and Nuanmanee Pongthana. 2000. Performance and Nature of Genetically Improved Farmed Tilapia: A Bioeconomic Analysis. *Aquaculture Economics and Management* 4(1–2): 83–101.

[13] Hussain, M.G., and M. A. Mazid. 2001. Aquaculture Genetics Research in Bangladesh. In Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics in Aquaculture, edited by Gupta, Modadugu, and Belen Acosta. *ICLARM Conference Proceedings* 64. p. 7–14. Manila.

are included (footnote 2). This indicates the significance of fishponds in the livelihood, nutrition, and social fabric of rural communities and households. Fish account for 60–80% of the animal protein consumed by the people of Bangladesh. In 1999, fish consumption per capita in inland areas (20 kg) was higher than the national average (15 kg). In 1998–1999, average tilapia consumption in selected inland areas was about 2.5 kg per capita, lower than consumption of silver carp (*Hypophthalmichthys molitrix*) (14 kg) and rohu (9.5 kg).[14] Among consumer groups in selected inland areas, the annual per capita tilapia consumption was 2.2 kg for rural fish producers and 2.6 kg for both rural nonproducers and urban consumers. If GIFT can raise the supply of farmed tilapia in Bangladesh, this would have a favorable impact on fish supply to meet the growing demand for fish among consumers, including the poor.

Environment and Biodiversity. Introductions of Mozambique tilapia and Nile tilapia to Bangladesh occurred long before the introduction of GIFT, and resulted in their wide establishment as alien species in open fresh- and brackishwaters, including Kaptai lake, where the Department of Fisheries introduced tilapia cage farming in 1982.[15] Subsequent introductions of Nile tilapia, including GIFT strains, are unlikely to have caused significant additional impacts on the natural environment and biodiversity, although all unquarantined fish movements carry the risk of spreading diseases. The GIFT introductions were made under the highly precautionary policies of the International Center for Living Aquatic Resources Management (ICLARM). As a member of INGA, Bangladesh follows INGA's voluntary protocols with respect to responsible movement of fish germplasm.[16] In common with many developing countries, Bangladesh lacks resources to enforce effective quarantine procedures for aquatic species.

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[14] Dey, Madan, Mohammad Rab, Ferdinand Paraguas, Somying Piumsombun, Ramachandra Bhatta, M. F. Alam, and Mahfuzuddin Ahmed. 2004. Fish Consumption in Selected Asian Countries. Paper presented at the Workshop on the Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia held at the Asian Development Bank, 17–20 March 2004, Manila, Philippines.

[15] Ireland, M.J., Tapash Kumar Roy, S.M. Nurun Nabi, M. A. Rahman, S.M. Ziaul Huque, and N. A. Aleem. 1999. *Are Tilapia Breeding in the Open Waters of Bangladesh? - The Result of a Preliminary Countrywide Survey. In The Fourth Indian Fisheries Forum Proceedings*, 24–28 November, 1996, Kochi, India. p. 423–426.

[16] Available: http://www.worldfishcenter.org/inga/

OVERALL ASSESSMENT

Tilapia farming has not yet contributed much to freshwater aquaculture production in Bangladesh because of institutional, technical, and socioeconomic constraints. These constraints include shortages of village extension workers, inappropriate extension material, lack of a reliable supply of quality tilapia seed, and limited access to financial capital. The Government has emphasized carp polyculture over other farmed fish. GIFT seed is not yet widely available, although supplies from private sector hatcheries are likely to increase. Without GIFT, however, interest in tilapia farming and overall support for aquaculture genetics would have remained lower than what has been achieved to date. GIFT R&D and INGA membership have enabled further selective breeding of GIFT, wider research partnerships, and acquisition of fish germplasm. New market opportunities for GIFT seed producers and tilapia farmers are expected to expand, because tilapia provide an affordable choice to fish consumers.

Although GIFT have good potential in Bangladesh, scaling-up tilapia production will depend on market forces, consumers' needs and preferences, and vigorous extension and promotional efforts. Ongoing efforts by nongovernment organizations to disseminate tilapia seed in northwest Bangladesh and in other regions are important steps to promote tilapia production. The demand for fish in Bangladesh will continue to grow, given the population growth rate of 1.8% per year (footnote 2) and the importance of fish in the Bangladeshi diet. There are indications that making GIFT broodstock more accessible to households engaged in rice-fish farming in northwest Bangladesh has begun to raise their production and consumption of tilapia.[17] Given the limited resources available to the Government, public-private partnerships are the key for expansion of tilapia seed production and distribution, and development of services to support tilapia farming and marketing. Wider availability of high-quality seed can facilitate tilapia farming in areas where most carps cannot be easily cultured; for example, tilapia have an advantage over carps in seasonal backyard ponds and water bodies that retain water for only 4–6 months. In the future, based on experience in other Asian countries, private hatcheries in Bangladesh could supply not only high-quality tilapia seed, but also technical advice and support services to farmers. For this, new and sustainable linkages are needed between private hatcheries and research centers.

[17] Barman, Benoy. 2000. Assessment of Nile Tilapia (*Oreochromis niloticus*) Seed Production and Growout Systems for Small-Scale Farmers in Northwest Bangladesh. Doctoral dissertation. Bangkok: Asian Institute of Technology.

Broader efforts are also needed to demonstrate low-cost tilapia farming technologies and to provide farmers with improved access to working capital.

Strategies for decentralized seed production have evolved in northwest Bangladesh. Such strategies involve the more easily bred and fast-growing species (including common carp, silver barb, and tilapia) that can be farmed by the poor.[18] Fish seed of these species can be produced, without access to major hatchery facilities, by using a small *hapa* (fine mesh net cage) suspended in a water body. The low-cost investment can enable resource-poor farmers to adopt the technology. However, there are constraints to basing fish seed supply on small, isolated broodstock populations. Unless decentralized fish seed production includes appropriate breeding strategies to maintain the genetic quality of broodstock, the performance of the production stocks will decline over time. Appropriate interventions to replenish high-quality seed for broodstock periodically require concerted efforts through participatory approaches involving farmers, government agencies, and nongovernment stakeholders to institutionalize improved rural fish seed supply.

[18] Little, David C., Israel Golder, and Benoy Barman. 1999. Rice Field-Based Fish Seed Production: Understanding and Improving a Poverty-Focused Approach to Promotion of Aquaculture in Bangladesh. *AARM Newsletter* 4(2): 7–10.

APPENDIX 4

Impacts of Genetically Improved Farmed Tilapia in Thailand

TILAPIA FARMING: RELEVANCE OF GENETIC IMPROVEMENT RESEARCH

Purpose and Scope. This appendix reviews impacts in Thailand of genetically improved farmed tilapia (GIFT), a product of research and development (R&D) efforts that were supported by technical assistance (TA) financed by the Asian Development Bank (ADB) and others during 1988–1997.[1] The tilapia strains that were bred and disseminated through these efforts are called GIFT, as are any tilapia bred subsequently using only GIFT genetic material. Tilapia that have been bred by combining GIFT and other tilapia genetic material are called GIFT-derived.[2] Other strains of tilapia farmed in Thailand are assigned here their historical and commonly used English names. For clarity, this appendix does not follow a recent decision in Thailand to call several distinct tilapia strains, including GIFT, by the same Thai name: Chitralada.[3]

Methods and Sources. Qualitative and quantitative methods were used, namely (i) reviews of existing studies and secondary documents; (ii) a survey of 116 tilapia hatcheries in the Central, Northern, Northeastern, and Southern regions, drawn from the records of the Department of Fisheries (DOF), provincial extension offices, and the Aquatic Animal Genetics Research and Development

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[1] (i) TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988. This R&D effort was also supported by the United Nations Development Programme and by research partner institutes.
(ii) TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia*, for $600,000, approved on 14 December 1993.

[2] No references are made in this report to specific generations of GIFT strains because there is no standard nomenclature. All GIFT are regarded here as a genetically improved breed of Nile tilapia, still under development.

[3] Under the proposed new Thai nomenclature, the strain of Nile tilapia that has been historically used most widely in Thailand for research and production will continue to be called Chitralada, as it is in this report. A Chitralada selected line, bred through support from the International Development Research Centre, Canada, but not released for commercial production, will be called Chitralada I. Genetically male Nile tilapia, developed from the Swansea strain with support from the Department for International Development, United Kingdom, will be called Chitralada II. GIFT will be called "Chitralada III."

Institute (AAGRDI); and (iii) in-depth key informant interviews. The Statistical Package for Social Sciences was used to process the survey data, to generate descriptive and inferential statistics, and to test for statistical significance of differences.

History of Tilapia Breeding. The first tilapia farmed in Thailand was the Mozambique tilapia (*Oreochromis mossambicus*), introduced from Malaysia in 1949. In the 1950s, DOF distributed this species widely, with assistance from the Food and Agriculture Organization of the United Nations. It was unpopular with farmers and consumers because of its poor performance and taste, but became widely established in open fresh- and brackishwaters. In 1965, His Imperial Highness Crown Prince Akihito of Japan sent Nile tilapia (*O. niloticus*) fingerlings to His Majesty the King of Thailand. These became the founder stock for the original Chitralada strain of Nile tilapia. By the 1980s, it was evident that the Chitralada strain was better for farming than the other widely used Nile tilapia strain (called Israel) and the hybrids between these two strains. The Chitralada strain was then chosen for national development of Nile tilapia farming. A population of Chitralada strain descended from the original introduction, maintained in ponds at the Chitralada Villa, Dusit Palace, Bangkok was confirmed as pure *O. niloticus*.[4] However, there were indications elsewhere that some other broodstock had been poorly managed. In 1984–1985, researchers found reduced performance, indicative of negative selection, in 17 of 30 Chitralada Nile tilapia populations examined at the Chiangmai Freshwater Fisheries Station and four private farms.[5]

Status of Tilapia Production. Farmed tilapia production in Thailand grew from 21,115 metric tons (t) in 1989 to 82,363 t in 2000 (Figure A4.1), contributing about 30% to total freshwater aquaculture production. The increase in tilapia production over this period was briefly disrupted by a decline in 1997, due in part to the decision of farmers in the Central, Eastern, and Western regions to grow shrimp (*Penaeus monodon*) in freshwater and low-salinity ponds in pursuit of higher profits. From 1998, there was a return to tilapia farming because the Government prohibited inland farming of shrimp in freshwater ponds.[6] In 2000, farmed Nile tilapia production comprised

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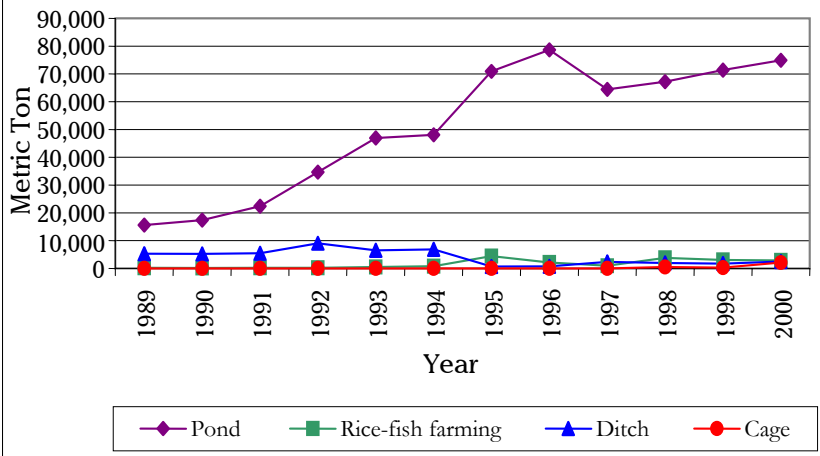
[4] McAndrew, Brendan. 1975. Electrophoretic Analysis of Tilapia from the Dusit Palace Stock, Thailand. *Report No. THA/75/012/WP6*. Programme for the Development of Pond Management Techniques and Disease Control. Bangkok: Department of Fisheries.

[5] Source: Aquatic Animal Genetics Research and Development Institute.

[6] In the absence of zoning, the rapid expansion of marine shrimp farms into freshwater areas of several provinces in Thailand has generated conflicts in uses of land and water resources. Salinity intrusion that affected freshwater ecosystems, rice fields, and

74,923 t from ponds, 2,870 t from rice-fish farming, 2,495 t from ditches, and 2,075 t from cages. Fish farming in ditches and cages accounted for the remainder. Total production of all farmed freshwater species in 2000 was about 271,000 t. In the same year, inland fisheries, mostly stocked reservoirs, produced 40,000 t of tilapia, one third of the total (farmed and fished) tilapia production of about 122,000 t.[7]

Figure A4.1: Farmed Tilapia Production in Thailand, 1989–2000
(metric ton)



Source: Department of Fisheries.

Tilapia seed is produced in hatcheries and nurseries from broodstock kept in ponds, fine mesh cages (termed *hapas*), and ricefields and associated small water bodies.[8] Tilapia are farmed as monocultures or in polyculture with native and alien carps and other species. Most tilapia farming is done in the irrigated areas of the Eastern, Western, and Central regions of Thailand. Some large private corporations are farming sex-reversed red and Nile tilapia for the

orchards was attributed to shrimp farming. This situation led to the enforcement, from December 1997, of Article 9 of the Environmental Act of 1996 to ban low-salinity shrimp farming in freshwater areas throughout the country.

7 Department of Fisheries. 2003. *Fisheries Statistics of Thailand.* Bangkok.

8 Seed means fry and fingerlings.

domestic and export markets, and plan to continue with tilapia farming in the next 5 years.[9]

ENABLING AND SUSTAINABILITY FACTORS

Tilapia Introductions. Table A4.1 summarizes important introductions of Nile tilapia to Thailand. The first was in 1965, when Nile tilapia of Egyptian origin were introduced to Thailand from Japan. These became the founder stock of the Chitralada strain, which soon acquired a good reputation.[10] From the late 1990s, other introductions of Nile, red, and other tilapia have been made by the private sector, particularly from Taipei,China.

Institutional Settings. Since the 1960s, DOF has been responsible for aquaculture and fisheries development in Thailand under a succession of National Economic and Social Development Plans (NESDPs). In 1973, DOF established the National Inland Fisheries Institute (NIFI) on the campus of Kasetsart University, Bangkok. This enabled close collaboration between DOF and academic researchers, including fish geneticists. A Fish Genetics Unit was established at NIFI in 1982 with a well-supported program of research and staff development.[11]

In 1989, Thailand opened the National Aquaculture Genetics Research Institute (NAGRI), renamed AAGRDI in 2002, under DOF. The AAGRDI facilities of 16 hectares (ha), 20 kilometers north of Bangkok, include modern laboratories, ponds, and hatchery tanks. These facilities constitute one of the world's largest establishments dedicated to aquaculture genetics research. AAGRDI currently employs 154 staff. This strong support has enabled further selective breeding of GIFT at AAGRDI and dissemination of GIFT to the provinces countrywide. In 1999–2000, AAGRDI received $85,500 from the Ministry of Agriculture and Cooperatives for dissemination of GIFT broodstock to inland fisheries stations to produce GIFT seed, and 37 million were distributed to 3,000 farmers. In 2001, AAGRDI

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[9] Male tilapia grow faster than females; mixed sex tilapia populations in ponds mature early and breed prolifically. Sex-reversed tilapia fry receive, for a short period, feeds containing methyltestosterone, posing no risks to consumers.

[10] Egyptian Nile tilapia have generally performed very well compared with other strains. See, for example: Eknath, Ambekar, et al. 1993. Genetic Improvement of Farmed Tilapias: The Growth Performance of Eight Strains of *Oreochromis niloticus* Tested in Different Farm Environments. *Aquaculture* 111: 171–188.

[11] This program was largely funded by the International Development Research Centre of Canada and organized in collaboration with Canadian universities, principally Dalhousie University, Halifax.

received a further $50,000 for this purpose, and provided 10 million GIFT seed to 1,000 public and private sector farmers.[12]

Table A4.1: Important Introductions of Nile Tilapia to Thailand, 1965–2000

Strain	Year	Source	Recipients	Purpose
Chitralada	1965	Japan	His Majesty the King of Thailand	First introduction
Israel	1982	Israel	NIFI	Research
Swansea	1992	CLSU, Philippines and University of Stirling, UK	NAGRI	Research
GIFT	1994	ICLARM, Philippines	NAGRI	Research
GIFT	1996	ICLARM, Philippines	NAGRI	Research
GIFT	1999	ICLARM, Philippines	NAGRI	Breeding program
GIFT	2000	GFII	NAGRI	Breeding program

CLSU = Central Luzon State University, GFII = Genetic Improvement of Farmed Tilapia Foundation International Incorporated, GIFT = genetically improved farmed tilapia, ICLARM = International Center for Living Aquatic Resources Management, NAGRI = National Aquaculture Genetics Research Institute, NIFI = National Inland Fisheries Institute, UK = United Kingdom.

Source: Aquatic Animal Genetics Research and Development Institute, Pathumthani, Thailand.

Thailand has long had a public sector network for multiplication and dissemination of fish seed. In 1966, His Majesty the King of Thailand gave 10,000 Chitralada strain fingerlings to DOF. In 1967, DOF began to distribute this strain to its 15 inland fisheries stations. From its foundation in 1989, NAGRI (the future AAGRDI) was linked to four DOF regional genetics centers, all responsible for testing and distributing fish strains.[13] AAGRDI now maintains breeding nuclei for tilapia and other species, with selectively bred lines, at its National Broodstock Center. This center distributes these selected lines to the four regional genetics centers, which then act as primary multipliers, distributing fish to become broodstock at public and private hatcheries, which in turn sell seed to farmers. The 57

[12] Source: Aquatic Animal Genetics Research and Development Institute.

[13] Regional genetics centers for inland aquaculture are located in the following provinces (regions): Burirum (Northeastern), Uttaradit (Northern), Chumphon (Southern), and Pathumthani (Central).

provincial inland fishery stations of DOF act as secondary multipliers, providing seed and technical advice directly to farmers. In 1972, DOF distributed 8.2 million tilapia fry, and by the late 1980s it was already distributing 20–25 million fry per year.[14] A network of fish seed traders, for sales and distribution of fish seed from private hatcheries to farmers, also became well established.

RESEARCH AND DEVELOPMENT

Tilapia genetics research in Thailand has been well supported, nationally and externally (Table A4.2). Since 1989, the Government has provided B124.2 million for development of AAGRDI facilities and acquisition of equipment, and B215.8 million for its operational costs, and continues to support its operations and expansion. In 2004, AAGRDI received $600,000 from the Government (1% of the total 2004 budget for DOF). During 2000–2003, B80.9 million was provided for AAGRDI operations from an agriculture sector program loan by ADB to the Government of Thailand.[15] Research undertaken by the Asian Institute of Technology (AIT), in partnership with DOF and others and based mostly on the Chitralada strain, has also contributed much to the development of tilapia hatchery technology and farming in Thailand.[16] Since 1992, AIT and DOF have participated in research for the development of genetically male tilapia (GMT) using a Nile tilapia strain from the University of Wales, Swansea, United Kingdom. Some large private sector hatcheries have also developed their own tilapia strains and hybrids. For example, the Charoen Pokaphand (CP) Food Company has developed the CP tilapia strain, bred with genetic material introduced from Taipei,China.

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[14] Source: Aquatic Animal Genetics Research and Development Institute.

[15] Loan 1698-THA: *Agriculture Sector Program Loan*, for $300 million, approved on 23 September 1999.

[16] AIT. 1994. *Partners in Development, the Promotion of Sustainable Aquaculture*. Bangkok.

Table A4.2: External Support for Aquaculture Genetics Research in Thailand, 1982–2004

Period	Activity	Funding Agency and Funds Provided ($)
1982–1986	Fish Genetics Project	International Development Research Centre, Canada ($146,000)
1990–1994	Aquaculture Development Coordination	European Union ($1,101,000)
1992–1995	Technology for Genetically Male Tilapia (GMT)	Department for International Development, United Kingdom ($19,550)
1994–1997	Dissemination of Genetically Improved Farmed Tilapia (GIFT)	Asian Development Bank ($50,000)

Source: Aquatic Animal Genetics Research and Development Institute.

DISSEMINATION AND EVALUATION OF GIFT

National and Regionwide Trials. In 1993, Thailand readily accepted an invitation from the International Center for Living Aquatic Resources Management (ICLARM) to become a national program partner in the Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA, footnote 1[ii]), together with Bangladesh, People's Republic of China, Philippines, and Viet Nam. Thailand's decision to participate reflected the high national importance of tilapia as farmed freshwater fish and the increasing emphasis on genetic research and fish breeding programs. GIFT were first introduced to Thailand in 1994 through DEGITA. Activities began with a baseline survey of the status of tilapia farming and its socioeconomic and environmental aspects, followed by rigorous comparative trials, on-station and on-farm, of the performance of GIFT and existing farmed Nile tilapia strains.

Standard Research Protocols. DEGITA employed standard protocols for comparing the performance of farmed tilapia within and among participating countries. The protocols included strict attention to quarantine of introduced GIFT, based on procedures used during the development of GIFT. The methodology for comparing tilapia strain performance involved communal stocking of tagged fish from all tilapia strains under comparison in diverse on-station and on-farm environments. This method was largely new to Thai researchers. Also, the use of ex-ante and ex-post assessments for economic analyses was new to Thai aquaculture researchers. Ex-ante

indicators, such as yields and production costs, provided early feedback at the start of adoption of GIFT, and contributed to further understanding of the dynamics between this new technology and existing socioeconomic and agroecological environments.

Overall Results. The results of on-station growth comparisons among GIFT, Chitralada, and GMT strains made through DEGITA were highly variable, and no consistent or significant rankings were possible. Subsequent on-farm trials in ponds indicated GIFT superiority in growth over local strains, increasing yields by about 38%.[17]

THAILAND IN THE INTERNATIONAL NETWORK ON GENETICS IN AQUACULTURE (INGA)

In 1993, Thailand became a founder member of INGA. Thailand identified its specific needs during the INGA foundation workshop: development of appropriate fish breeding strategies and wider dissemination of improved breeds of tilapia and indigenous species.[18] INGA membership widened the international linkages and research partnerships of Thai aquaculture geneticists in the Asia-Pacific and other regions. In addition to GIFT introduced through DEGITA in 1994 and 1995, Thailand received through INGA further introductions of GIFT from the Philippines in 1996, 1998, and 2000, and tilapia germplasm from other INGA members for research and breeding purposes.[19] INGA has also enabled exchanges between Thailand and other INGA members of germplasm of carps.[20] During 1995–2003, a total of 24 Thai technical staff received training in aquaculture genetics through courses organized by INGA.

OUTCOMES AND IMPACTS

National Tilapia Breeding Program. The performance of GIFT during DEGITA and their breeding history led DOF to choose GIFT for

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[17] ICLARM. 1998. *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia: Final Report*. Manila.

[18] ICLARM. 1993. *Summary Proceedings of the Workshop on Networking for Genetics in Aquaculture*. Manila.

[19] For example, blue tilapia (*Oreochromis aureus*) from Egypt. Source: WorldFish Center, Penang.

[20] For example, Thailand received common carp (*Cyprinus carpio*) strains from Viet Nam in 1995 and Indonesia in 1998, and improved rohu (*Labeo rohita*) from India in 1998. Source: WorldFish Center, Penang.

its national tilapia program. The high genetic variability of GIFT [21] is a good basis for selective breeding. The choice of GIFT was concurrent with a decision of DOF to cease selective breeding research on the Chitralada strain. From 1998, GIFT have been regularly disseminated from this new national tilapia breeding program at AAGRDI to public and private hatcheries and farmers nationwide (Table A4.3).

Table A4.3: Genetically Improved Farmed Tilapia Seed Distributed by the Department of Fisheries of Thailand to Public and Private Establishments, 1998–2002

	Millions of Fry and Fingerlings Distributed Annually (Numbers of Hatchery and Farm Recipients)					
Source	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Government	0.0	0.9	1.0	1.1	1.1	4.1
	(0.0)	(35.0)	(40.0)	(45.0)	(49.0)	(169.0)
Private:						
Commercial	0.1	0.4	0.5	0.6	0.6	2.2
	(10.0)	(12)	(15.)	(18.0)	(20.0)	(75.0)
Small-Scale	0.8	4.5	8.8	2.2	3.6	19.9
	(8.0)	(220.0)	(570.0)	(190.0)	(330.0)	(1,318.0)
Total	**0.9**	**5.8**	**10.3**	**3.9**	**5.3**	**26.2**
	(18.0)	**(267.0)**	**(625.0)**	**(253.0)**	**(399.0)**	**(1,562.0)**

Source: Aquatic Animal Genetics Research and Development Institute.

Wider Choice of Tilapia Strains for Farmers. Prior to the availability of GIFT in Thailand, tilapia farmers were farming Chitralada, GMT, red tilapia, and other local strains. Their choice thereafter became wider, including GIFT and GIFT-derived strains and hybrids. In the hatchery survey undertaken for this study, respondents were asked to give scores of 1–10 for certain performance characteristics (growth, survival, time to maturation, fecundity, and color) of their chosen strains.[22] Responses tended to merge to a narrow range of scores at the upper end of the scale. Nevertheless, some statistically significant differences in perceived performance were discernable. The difference between the mean

[21] (i) Romana-Eguia, Maria Rowena, Minoru Ikeda, Zubaida Basiao, and Nobuhiku Taniguchi. 2004. Genetic Diversity in Farmed Asian Nile and Red Tilapia Stocks Evaluated from Microsatellite and Mitochondrial DNA Analysis. *Aquaculture* 236: 131–150;
(ii) Rutten, Marc, Hans Komen, R. Deerenberg, M. Siwek, and Henk Bovenhuis. 2004. Genetic Characterization of Four Strains of Nile Tilapia (*Oreochromis niloticus* L.) Using Microsatellite Markers. *Animal Genetics* 35: 93–97.

[22] The scores obtained from the survey represent perceived characteristics of tilapia strains, in the absence of actual measurement and analysis of their performance traits in respondents' hatcheries.

score for GIFT growth (8.50) and that for Chitralada growth (7.52) was statistically significant ($p<0.05$), as was the difference between the mean scores for growth of GIFT and of all nonGIFT strains pooled (7.17). This difference was higher still when GIFT was compared with that for local strains (6.75). With a mean score of 7.82, GIFT also outscored significantly the pooled nonGIFT strains (7.17) on farmers' preference for light body coloration in tilapia. The difference between the mean scores for body coloration of GIFT and local strains (6.93) was larger and statistically significant ($p<0.01$). There was no significant difference between the mean scores for body coloration of GIFT and Chitralada (7.33).

Impacts on Tilapia Production. The dissemination of GIFT to Thailand and its use in a national tilapia breeding program and in public and private tilapia farming nationwide have undoubtedly contributed to farmed tilapia production. However, these contributions cannot be estimated directly from production statistics. The DOF production statistics (footnote 7) indicate freshwater farmed tilapia only as Nile tilapia, not disaggregated by strain. The contributions of the different Nile tilapia strains to total seed production could be used as approximate indicators of their relative contributions to farmed tilapia production, but there are also no reliable statistics for overall countrywide tilapia seed production.

In the absence of reliable statistics, a national survey of tilapia hatcheries was conducted for this study to generate information on Nile tilapia seed production by strain. The results (Table A4.4) show that GIFT accounted for 46% of the 576 million tilapia seed sold by these hatcheries in 2003, up from 36% in 2001.[23] The CP strain was the next most widely sold strain (39%) in 2003, through exclusive sales to the CP Food Company's contract farmers**.** If these "exclusive to contractee" sales of the CP strain are excluded, the share of GIFT in the remaining tilapia seed production in 2003 was 75%. The third most popular strain was Chitralada, the shares of which were relatively stable at about 7–8% over this period, followed by local strains of unknown origin, probably derived from Chitralada. The share of local strains decreased from 10% in 2001 to 7% in 2003, probably indicating a greater concern among farmers to buy high-quality tilapia seed of known provenance. When the hatchery respondents were asked about the tilapia strains (multiple responses) that they would sell in the next 5 years, GIFT emerged as the most popular choice across all hatchery sizes. Thus, the use of GIFT in tilapia production is most likely to be sustained.

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[23] In terms of the value of tilapia seed sold, GIFT hatcheries covered by the survey earned B64 million in 2003, up from B38 million in 2001. This translates to a growth in the share of tilapia sales from 37% to 47% over this period.

Table A4.4: Tilapia Seed (Fry and Fingerling) Sales and Market Shares by Strain in Thailand, 2001 and 2003

Tilapia Strain	Millions of Seed Sold 2001	Millions of Seed Sold 2003	% Market Share 2001	% Market Share 2003
Genetically Improved Farmed Tilapia (GIFT)	162.5	264.9	36.3	46.0
Charoen Pokaphand (CP)	200.0	224.0	44.6	38.9
Chitralada	35.2	39.7	7.9	6.9
Local (nonidentifiable strains)	47.2	39.0	10.5	6.8
"Taiwan"	1.6	7.6	0.4	1.3
Genetically Male Tilapia (GMT)	1.6	0.8	0.3	0.1
Total	**448.1**	**576.0**	**100.0**	**100.0**

Source: Impact Evaluation Study, 2004 survey of Thai hatcheries.

The optimism of GIFT hatchery respondents about producing tilapia in the next 5 years was evident in their plans to continue (77%) or to expand (15%) their scale of operations because of attractive profitability. Only 3% of the respondents anticipated a reduction in operations due to uncertain market prospects, while the rest (5%) were undecided because of earlier financial losses and perceptions of uncertainty. The nonGIFT hatcheries (such as those producing Chitralada, GMT, "taiwan," and CP strains) also confirmed that they planned to continue their operations. For hatcheries producing local tilapia strains, 19% of the respondents were unclear about their future plans, due largely to a decline in demand for their products. More large-scale than medium-scale and small-scale hatchery operators saw themselves expanding their operations in the next 5 years.[24] Thus, large-scale hatcheries, which accounted for 66% of the total sales volume of tilapia seed in 2003,[25] will increasingly determine the availability of different tilapia strains in Thailand.

Impacts on Income from Tilapia Farming. Farming in ponds, which is the dominant method of farming tilapia in Thailand, generates attractive net returns.[26] At present, the indicative net returns per ha from farming GIFT are B176,000 per 8-month crop cycle. For a

[24] Hatcheries were defined according to their annual fingerling production capacity: large (>60 million), medium (12–60 million), and small (<12 million).

[25] In 2003, the market shares of small- and medium-scale hatcheries were 22% and 12%, respectively.

[26] Net returns are defined as total revenues from sales of tilapia less total production costs and marketing expenses. Production costs include both cash costs and noncash costs, where noncash costs refer to depreciation and imputed family labor.

6-month crop cycle, the net returns per ha are B74,000–137,000, due largely to differences in production cost and in farm gate prices of tilapia. Tilapia harvests from ponds are 7–11 t/ha per crop cycle, with an average fish survival rate of 80% from stocking to harvest.[27]

Based on the hatchery survey conducted for this study, GIFT hatchery respondents perceived profitability (2003 versus 2001) as stable due to a continuing demand for the GIFT strain and sustained marketing efforts. GIFT hatchery respondents expressed optimism about a marked improvement in profitability over the next 5 years.[28] NonGIFT hatchery respondents, except those using local strains and GMT, perceived profitability as stable in 2001–2003. Those using local strains and GMT perceived that profitability was declining and generally attributed this to weakening demand for their tilapia strains and increasing production costs. Over this period, the market shares of local strains and GMT in tilapia seed sales shrank relative to GIFT.

Impacts on Employment. The dissemination of GIFT and GIFT-derived strains has provided opportunities for employment in tilapia hatcheries and farms. There are no statistics for the total number of people employed in tilapia farming and associated activities, such as pond excavation, cage and net making, fish feeding, fish harvesting, sorting/grading, marketing, and transportation. However, it was estimated that at least 200,000 people, including their families, directly benefited from employment generated by tilapia farming.[29] This does not include additional full-time, part-time, and seasonal labor required by tilapia farms and by allied industries, such as tilapia feed processing, supply of fertilizers, tilapia seed and other inputs, and their respective distribution.

Based on the hatchery survey conducted for this study, the mean hatchery workforce in 2003 was 1.7 persons/ha. Overall, men comprised 77% of the workforce of the hatcheries surveyed for this study. GIFT hatcheries contributed 45% of the total direct employment in the surveyed hatcheries.

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[27] For a typical tilapia cage (3 x 6 x 2.5 meters) in Northern Thailand, the indicative net return is B4,285 per 4-month crop cycle, from an average yield of 1 t/cage. The survival rate is 90%, attributed to the advanced tilapia fingerlings (30 grams each) used in stocking cages. On average, a tilapia cage farmer in Northern Thailand who raises tilapia as a secondary income source has 4 cages and 2–3 crop cycles per year. Estimates of net returns from farming GIFT in cages as well as in ponds were based on key informant interviews.

[28] Respondents were asked to rate their profitability on a scale of 1–10, where 1 is the least profitable and 10 is the most profitable level. The difference in the ratings between the two years under comparison was subjected to a t-test for statistical significance ($p<0.01$).

[29] Staff estimates.

Impacts on Human Nutrition. Fish is a major source of animal protein, essential fatty acids, minerals, and vitamins for Thai people. In 1998–1999, average annual fish consumption was about 29 kilograms (kg), mostly as fresh fish. Across various regions of Thailand, tilapia was the most preferred freshwater fish species (8.5 kg/capita/year), followed by silver barb (*Barbodes gonionotus*) (4.7) and snakehead (*Channa striata*) (4.4).[30] A 1998–1999 survey of fish consumers indicated substantially higher annual per capita tilapia consumption of 31.6 kg by rural tilapia producers; 30.5 kg by rural nonproducers; and 23.5 kg by urban nonproducers. In 1999, the average retail price of silver barb, a widely available and low-priced freshwater fish, was $0.72/kg, slightly higher than that for tilapia ($0.69/kg).[31] These surveys were conducted in selected inland areas, which explain the relatively high tilapia consumption levels. The main reasons cited by consumers for preferring tilapia were good taste, availability, easy preparation, and reasonable price.

As a relatively low-priced fish in Thailand (Table A4.5), more than 90% of current tilapia production is marketed domestically, providing a widely available and affordable fish for poor consumers in rural and urban areas. The poorest income group in Thailand spent more of its fish expenditures on tilapia than the highest income group (25% versus 13%) in 1998–1999. Tilapia was a more affordable source of protein for the poor than was snakehead ($1.70/kg retail) and chicken ($1.52) (footnote 31). The widening use of GIFT indicates its current and potential future contribution to human nutrition in Thailand. This is likely to increase as the public and private sectors increase the use and further improve the performance of the GIFT strains.

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[30] Somying Piumsombun. 2001. *Production, Accessibility and Consumption Patterns of Aquaculture Products in Thailand.* Available: http://www.fao.org/docrep/004

[31] Dey, Madan, Mohammad Rab, Ferdinand Paraguas, Somying Piumsombun, Ramachandra Bhatta, Mohammad Ferdous Alam, and Mahfuzuddin Ahmed. 2004. Fish Consumption in Selected Asian Countries. Paper presented during the Final Workshop on the Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia, held at the Asian Development Bank, 17–20 March 2004, Manila, Philippines.

Table A4.5: Average Retail Prices of Freshwater Fish Species in Selected Thailand Provinces in 2000
(baht/kg)

Fish Species	Bangkok	Ang Thong	Chantaburi	Khon Kaen	Udon Thani	Nakon Sawan	Pitsanuloke	Chiangmai	Pattani	Phuket	Songkhla
Walking Catfish	23.57	18.88	23.40	36.54	38.19	19.23	28.96	32.84	27.56	37.25	32.62
Snakehead	49.09	44.19		56.05	67.10	59.39	49.35	62.24	35.89		50.82
Mrigal	10.52			32.44	28.96	21.64	31.06	30.00	30.00		30.00
Tilapia	16.14	16.37	15.22	32.52	35.16	26.42	31.24	31.10	37.77	34.95	38.06
Silver Barb	16.30	13.86	23.32	30.00	33.89	21.23	28.76	29.89	30.67	26.27	34.75
Giant Gourami	15.00	50.00				39.94	41.36				
Rohu	13.18	20.00	25.00	29.79	35.48	19.28	25.00	29.31	39.23	30.01	30.34
Snakeskin Gourami	44.08	50.00		24.35		49.09	25.00		40.00		36.26

kg = kilogram.
Source: Department of Fisheries. 2003. *Freshwater Fish Farm Production 2000*. Bangkok.

Impacts on Research and Development. GIFT and related outcomes, especially INGA membership, have had substantial and favorable impacts on R&D for genetic improvement of farmed fish in Thailand. The GIFT R&D methodology has been well published and is available in Thailand.[32] In addition to the introduction of new research methods and associated training, GIFT R&D has influenced national decisions to participate in TA to improve other farmed fish species. Thailand has participated, with other INGA members, in ADB-financed regional TA for the genetic improvement and dissemination of farmed carp species.[33]

Impacts on Policy. Under Thailand's NESDPs, policies for rural aquaculture have emphasized the following: reducing malnutrition (NESDP 5, 1982–1986), accelerating fish farming activities (NESDP 6, 1987–1991), establishment of individual fishponds (NESDP 7, 1992–1996), and managing community fish ponds (NESDP 8, 1997–2001). The current National Fisheries Policy calls for increasing farmed fish production by 5% per year and considers freshwater aquaculture as contributing mainly to domestic fish consumption, especially to benefit the poor, and coastal aquaculture as contributing to seafood exports. Tilapia are priority species for freshwater aquaculture, but R&D is also being supported to develop salt-tolerant tilapia for coastal aquaculture. Despite the dominance of domestic consumption of tilapia, Thailand also exports modest amounts and competes with other tilapia-producing countries for the whole frozen and tilapia fillet markets in Australia, Europe, and North America. In 2000, documented tilapia exports from Thailand totaled 278 t, worth $647,000.[34]

Impacts on Biodiversity and the Environment. Introductions of alien species for aquaculture, together with the effects of other interventions such as overfishing, pollution, siltation, and water abstraction, can threaten aquatic biodiversity and the environment. Prior to the introductions of GIFT, Nile tilapia was already a firmly established alien species in Thai inland waters, not only through escapes from aquaculture but also through regular, purposeful

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[32] (i) Acosta, Belen, and Ambekar Eknath. 1998. *Manual on Genetic Improvement of Farmed Tilapia (GIFT) Research Methodologies*. Manila: ICLARM;
(ii) WorldFish. 2004. *GIFT Technology Manual: An Aid to Tilapia Selective Breeding.* Penang: WorldFish Center.

[33] (i)TA 5711-REG: *Genetic Improvement of Carp Species in Asia*, for $1.3 million, approved on 12 December 1996.
(ii)TA 6136-REG: *Achieving Greater Food Security and Eliminating Poverty by Dissemination of Improved Carp Species to Fish Farmers*, for $ 0.95 million, approved on 11 November 2003.

[34] Department of Fisheries, Bangkok.

stocking for inland fisheries. Nile tilapia does not appear to have been problematic in Thailand or in many other countries outside its natural range.[35] The introductions of GIFT to Thailand were made under the highly precautionary policies of ICLARM. They are unlikely to have caused any significant impacts on the natural environment and biodiversity additional to those already made by prior introductions of Nile and other tilapia. However, for Nile tilapia, as for any alien aquatic species, a precautionary approach is needed with respect to water bodies and watercourses in which it has not previously been introduced. This applies particularly to pristine and near pristine waters that support important populations of Thai native aquatic flora and fauna. This precautionary approach is usually lacking in most countries, once an alien aquatic species is within national borders. Ecosystem borders are the more important consideration.

Thailand follows INGA's voluntary protocols with respect to germplasm movements. Its national regulations on fish quarantine and biosafety are extensive but not yet completely enforceable, particularly with respect to private sector introductions of aquatic organisms for aquaculture and for the aquarium trade. This situation puts at risk not only wild biodiversity and the natural environment but also the biodiversity and genetic resources of Thai aquaculture. Many who introduce and distribute alien aquatic species are insufficiently aware of this or disinclined to adopt more precautionary and responsible behavior with respect to fish movements and quarantine.

OVERALL ASSESSMENT

The main impacts in Thailand of the 1994 introduction of GIFT through participation in DEGITA (footnote 1[ii]) are the choice of GIFT for the national tilapia breeding program at AAGRDI and the dissemination of GIFT nationwide. Without GIFT, this national effort would have had to rely on the tilapia strains previously available in Thailand or on making introductions of other new tilapia genetic material. The continued use of the Chitralada and other strains available in Thailand before the introduction of GIFT was an option. These could have been used for more sustained and systematic attempts at genetic improvement and tilapia breeding programs than are apparent from the history of tilapia farming in Thailand. However,

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[35] Pullin, Roger, Maria-Lourdes Palomares, Christine Casal, Madan Dey, and Daniel Pauly.1997. Environmental Impacts of Tilapias. In *Tilapia Aquaculture. Proceedings of the Fourth International Symposium on Tilapia in Aquaculture,* edited by Kevin Fitzsimmons. Volume 2. Ithaca, NY: Northeast Regional Agricultural Engineering Service Cooperative Extension. p. 554–570.

the acquisition of GIFT, with their comparative advantages (performance, documented breeding history, and high genetic diversity), met the need in Thailand for a national program of tilapia genetic improvement, based on selective breeding. The notable institutional impacts are strengthened national research capacity and increased international linkages and partnerships, mainly through membership in INGA.

Future Challenges. The need for genetic improvement of farmed tilapia in Thailand will continue indefinitely, with strategic decisions to be made from time to time with respect to the genetic material and the methods to be used. GIFT have been chosen for the current national tilapia breeding program, but other strains and hybrids will become available as tilapia breeding develops in the Asia-Pacific and other regions. In this context, control and quarantine of fish introductions and safeguarding fish health are particularly important. Selective breeding is likely to remain the main approach to genetic improvement of farmed tilapia. It can be applied to develop tilapia breeds for specific farm environments, including brackishwater farms.

The public (government and universities) and private sectors have important and complementary strengths and opportunities to serve the needs of tilapia seed producers and farmers. The public sector has continued the national tilapia breeding program and related research, although it will require sustained, and in some areas increased, financial support. In particular, the gene banking of tilapia and other important genetic resources of farmed fish will need to be strengthened to underpin future breeding programs. The private sector could take a greater role in tilapia breeding and related research, and there is high potential for public-private partnerships, given clear policies to foster their establishment and sustainability.

The government, research institutes, and development agencies face difficult challenges to keep abreast of the rapid development of tilapia farming. Current statistics do not capture adequately the dynamics and diversity of tilapia farming. The large-scale private sector is likely to assume greater prominence in tilapia farming in Thailand, especially in tilapia seed production, where small-scale hatcheries will probably find it increasingly difficult to compete. The hatchery survey conducted for this study indicated that the market share of sex-reversed tilapia seed in Thailand will likely increase from 28% in 2003 to about 48% over the next 3 years.

APPENDIX 5

Impacts of Genetically Improved Farmed Tilapia in Viet Nam

TILAPIA FARMING: RELEVANCE OF GENETIC IMPROVEMENT RESEARCH

This appendix reviews impacts in Viet Nam of genetically improved farmed tilapia (GIFT), a product of research and development (R&D) efforts that were supported by technical assistance financed by the Asian Development Bank and others during 1988–1997.[1] The tilapia strains that were bred and disseminated through these efforts are called GIFT strains, as are any tilapia bred subsequently using only GIFT genetic material. Tilapia that have been bred using GIFT and other tilapia genetic material are called GIFT-derived.[2]

Tilapia farming in Viet Nam began after the introduction of the Mozambique tilapia (*Oreochromis mossambicus*) in 1951, but did not prosper because of the poor growth of this species. In 1973, Nile tilapia (*O. niloticus*) was introduced from Taipei,China to southern Viet Nam and in 1977 was made available to the Research Institute for Aquaculture (RIA) No. 1, Bac Ninh, near Hanoi. Up to the early 1990s, however, most tilapia farmers used seed (fry and fingerlings) from hatcheries that kept poorly managed broodstocks and produced slow-growing seed of hybrids between *O. niloticus* and *O. mossambicus*.

During the 1980s and 1990s, the total annual production of tilapia in Viet Nam was about 7,000–8,000 tons (t), mostly from ponds and ricefields.[3] Introductions and testing of commercially farmed and experimental Nile tilapia strains began in 1994, concurrently with expansion of R&D for tilapia genetics and seed supply, including

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[1] (i) TA 5279-REG: *Genetic Improvement of Tilapia Species in Asia*, for $475,000, approved on 8 March 1988. This R&D effort was also supported by the United Nations Development Programme (UNDP) and by research partner institutes.
(ii) TA 5558-REG: *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia*, for $600,000, approved on 14 December 1993.

[2] No references are made in this report to specific generations of GIFT, because there is no standard nomenclature. All GIFT are regarded here as a genetically improved breed of Nile tilapia, still under development.

[3] Source: Research Institute for Aquaculture No. 1.

technology for producing all-male seed by sex reversal.[4] By 2003, national tilapia production had grown to about 30,000 t, contributing about 5% of total freshwater aquaculture production. The Ministry of Fisheries now plans substantial expansion of tilapia farming. The target for 2010 is 200,000 t, to be farmed mainly in the Mekong and Red River deltas and the economically depressed central highlands.[5]

ENABLING AND SUSTAINABILITY FACTORS

Tilapia Introductions. From 1994, there were important, well-documented introductions of Nile tilapia to Viet Nam (Table A5.1). There were also other, poorly documented introductions, especially from the People's Republic of China (PRC) and Thailand. In 2002, PRC strains of Nile tilapia and blue tilapia (*O. aureus*) were introduced to the National Center for Fisheries Extension. During 1983–2001, red tilapia (hybrids of *Oreochromis* species) were also introduced from various sources (e.g., Cuba; Taipei,China; and Thailand). However, Nile tilapia remains the preferred species for tilapia farming in Viet Nam. The GIFT introduced in 1997 became the basis for a national tilapia breeding program, using the same selective breeding methods as employed in the original GIFT R&D.

Institutional Settings. Aquaculture genetics in Viet Nam began in the 1970s, with crossbreeding of common carp (*Cyprinus carpio*) strains at RIA No.1, which thereafter became the leading national center for aquaculture genetics research and expertise.[6] RIA No. 2 in Ho Chi Minh City and its associated Research Centre for Aquaculture Development in the Mekong Delta at Cai Be, Tien Giang, have been involved in R&D and training for tilapia farming since the 1980s. Can Tho University and the University of Agriculture and Forestry, Ho Chi Minh City, have also made substantial contributions. RIAs Nos. 1 and 2, as well as RIA No. 3 at Nha Trang, are currently being developed to support aquaculture in the northern, southern, and central regions, respectively. The three RIAs will host three national broodstock

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[4] Male tilapia grow faster than females; mixed-sex populations in ponds mature at small sizes and breed prolifically. Sex-reversed tilapia fry receive, for a short period, feeds containing methyltestosterone, posing no risks to consumers.

[5] Ministry of Fisheries. 2002. *Development of Tilapia Culture in the Period 2003–2010*. Hanoi.

[6] From the early 1990s, RIA No. 1 has been the main national institute for tilapia breeding, despite its cold northern location, which shortens spawning and growing seasons.

centers.[7] These developments reflect the high priority given to aquaculture development.[8]

Table A5.1: Introductions of Nile Tilapia to Viet Nam, 1994–2002

Nile Tilapia Strain	Year(s)	Source	Recipient(s)	Purpose(s)
GIFT	1994	ICLARM	RIA Nos. 1 and 2	Research
Egypt Strain	1994	ICLARM	RIA Nos. 1 and 2	Research
Thailand Strain	1994–1996	AIT, Bangkok	RIA No. 1; Can Tho University; and the University of Agriculture and Forestry, Ho Chi Minh City	Research and Production
GIFT	1996	ICLARM	RIA Nos. 1 and 2	Research
GIFT	1997	ICLARM	RIA Nos. 1 and 2	Genetic Improvement
Swansea	1997–1999	University of Wales, Swansea, UK	RIA Nos. 1 and 2	Research and Production

AIT = Asian Institute of Technology, GIFT = genetically improved farmed tilapia; ICLARM = International Center for Living Aquatic Resources Management, RIA = Research Institutes for Aquaculture, UK = United Kingdom.
Source: Research Institute for Aquaculture No. 1.

Private sector tilapia hatcheries and farms in Viet Nam range in size and sophistication from household ponds and rice fields to large, highly engineered pond and cage enterprises. In addition to the RIAs, some provinces have large public sector hatcheries, supplying seed and technical advice to farmers. Tilapia seed supply and farming in Viet Nam are developing rapidly and are highly dynamic. Tilapia seed producer and farmer associations have not developed. However, private and public sector cooperation is well established at the national, provincial, and local levels, and will expand with increased investment in tilapia farming.

Tilapia Genetics Research and Breeding. National institutes, particularly the RIAs, have attracted considerable external support to

[7] National Broodstock Center No.1 at the new RIA No. 1 site, Hai Duong, is already operational in tilapia breeding, gene banking, and broodstock supply.

[8] For example: Decision of the Prime Minister No. 224/1999/QD-TTG. *Approval to Aquaculture Development Program in the Period 1999–2010*. Hanoi, 8 December 1999. Government of the Socialist Republic of Viet Nam.

which national support (Tables A5.2 and A5.3) is often linked, such as selective breeding of GIFT, cofunded by the Ministry of Fisheries of Viet Nam and the Norwegian Agency for Development Cooperation (NORAD). Sustaining the contributions of national institutes to R&D for tilapia genetics research and breeding and to related extension and provision of technical advice is still largely dependent on such cofunding. The three national broodstock centers, associated with RIAs Nos. 1, 2 and 3, are also being developed and supported by a combination of national and external funding.[9] The private sector in Viet Nam is not yet significantly engaged in R&D for tilapia genetics and breeding.

Table A5.2: External Support for Tilapia Genetics in Viet Nam 1994–2003

Period	**Activity**	**Source** (funds provided)
1994–1996	Strain comparisons; hatchery technology	Asian Institute of Technology, Bangkok ($20,000)
1994–1997	On-station and on-farm GIFT trials	Asian Development Bank and International Center for Living Aquatic Resources Management ($70,000)
1997–2000	On-farm trials with genetically male tilapia	Department for International Development, United Kingdom ($45,000)
1999, ongoing	Selective breeding of GIFT	Norwegian Agency for Development Cooperation ($126,760)

GIFT = genetically improved farmed tilapia.
Source: Research Institute for Aquaculture No. 1.

[9] Up to 2004, all of the total funds ($2,255,000) allocated for development of National Broodstock Center (NBC) No.1 (northern region) had been invested, comprising $2,123,000 of national funds and $127,000 from the Danish International Development Agency (DANIDA), with 15% devoted to tilapia breeding and seed supply. The corresponding funds allocated for development of NBCs Nos. 2 (southern region) and 3 (central region) are, respectively, $2,307,000 ($2,180,000 national + $127,000 from DANIDA) and $1,750,000 ($1,650,000 national + $100,000 from DANIDA). NBCs Nos. 2 and 3 will devote, respectively, 20% and 10% of their work to tilapia.

Table A5.3: National Support for Tilapia Genetics in Viet Nam 1994–2003

Period	Activity	Source (funds provided)
1999–2000	Selective breeding of GIFT	Ministry of Fisheries ($30,000)
1997–1999	Development of genetically male tilapia	Ministry of Science and Technology ($50,000)
2000	Hybridization for all-male tilapia seed	Ministry of Fisheries ($15,000)
2001–2003	Dissemination of GIFT	National Center for Fisheries Extension ($ 60,000)
2002–2003	Training on sex-reversal of tilapia seed	National Center for Fisheries Extension ($ 20,000)

GIFT = genetically improved farmed tilapia.
Source: Research Institute for Aquaculture No. 1.

Dissemination of Tilapia Strains. The dissemination of GIFT and other tilapia strains in Viet Nam remains largely dependent on public sector organizations and is constrained by limited financial resources and institutional arrangements. These constraints are only now beginning to be overcome. In the late 1990s, interest in tilapia farming and awareness of the importance of improved tilapia strains were still limited. Demand for GIFT began to grow as RIA No. 1 expanded its efforts to promote and develop their use. By 2001, RIA No.1 had distributed only about 200,000 GIFT seed, mostly to nearby, northern hatcheries. In 2002, with NORAD support and facing a wider demand for GIFT, RIA No. 1 distributed, to each of 61 provincial hatcheries, 25,000 GIFT seed from its selective breeding program based on the GIFT introduced in 1997. This dissemination of GIFT will have varied degrees of success, according to the capabilities of the recipients, but was a significant step toward the wider availability of GIFT in Viet Nam. Some private tilapia hatcheries are beginning to specialize in producing GIFT seed.[10]

The continuing distribution of Thailand and other Nile tilapia strains, as well as *O. mossambicus* x *O.niloticus* hybrids, prevents thorough documentation of the breeding histories of most of the tilapia currently farmed in Viet Nam. Some private hatcheries and seed traders continue to introduce and distribute tilapia seed from

[10] A large private hatchery in Ho Chi Minh City produced and sold on average 6 million sex-reversed GIFT fry and fingerlings per month in 2003 and 18 million in February 2004 alone (70% of its total production capacity). Source: Hatchery visits made in 2004 for this study.

other countries.[11] All of these tilapia can interbreed. Consequently, it is not currently possible to determine the exact contributions of GIFT and GIFT-derived strains to overall seed supply and production. What some hatchery operators and farmers call GIFT could be a variety of strains and hybrids, some of which are not necessarily GIFT or GIFT-derived. This confused situation should, however, improve. The earthen pond hatcheries around Ho Chi Minh City that have long produced poorly documented tilapia hybrids are now in decline because of urban development, and there is an increasing demand by public and private hatcheries for Nile tilapia strains with known breeding histories. Moreover, the national broodstock centers, provincial hatcheries, and the private sector are beginning to emphasize breed identity and to improve broodstock management.

CATALYTIC EFFECTS OF DISSEMINATION OF GIFT

Joining DEGITA. In 1994, Viet Nam became a national program partner in the Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia (DEGITA, footnote 1[ii]), undertaking to conduct on-station and on-farm trials to compare the performance of GIFT Nile tilapia strains with others available in Viet Nam.[12] Viet Nam joined DEGITA recognizing that its tilapia farmers would benefit from high-quality tilapia seed. RIAs Nos.1 and 2 and Hanoi Agricultural University were the national partners, together with farmers for on-farm trials. DEGITA began with a comprehensive baseline survey of the status of tilapia farming in Viet Nam, together with reviews of socioeconomic and environmental aspects of tilapia farming. DEGITA stipulated the use of standard protocols for on-station and on-farm comparative trials among the tilapia strains farmed in Viet Nam and GIFT. The on-station research protocols were similar to those used previously in Viet Nam, but those for on-farm trials were new to national researchers and have since been adopted by the RIAs for research with tilapia and other species.

Choice of GIFT for a National Tilapia Breeding Program. Growth and survival of GIFT and other Nile tilapia strains (Egypt, Thailand, and local Vietnamese) were compared on-station at RIAs Nos.1 and 2. On-farm comparisons of the growth and survival of GIFT and Thailand strains in ponds were made in northern and southern

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[11] For example, from the PRC and Thailand. Source: Research Institute for Aquaculture No.1.

[12] ICLARM.1998. *Dissemination and Evaluation of Genetically Improved Tilapia Species in Asia: Final Report*. Manila.

provinces, at locations representing coastal, lowland, and upland conditions. The results were variable, both on-station and on-farm. In trials undertaken during 1994–1996, the GIFT strain, with some exceptions, had generally higher growth beyond the fry stage and higher weights at harvest (6–22%) than the locally adapted Vietnamese strains (footnote 12). GIFT and Thailand strains showed similar performance overall. Consequently, GIFT and Thailand strains were then chosen for dissemination countrywide. However, the good growth, survival, and high genetic variability of the GIFT strain were then considered reasons enough for it to be preferred to the Thailand strain and to become the strain chosen for a national tilapia breeding program at RIA No.1. After two generations in that breeding program, the response to selection for growth was 16%.[13]

VIET NAM IN THE INTERNATIONAL NETWORK ON GENETICS IN AQUACULTURE (INGA)

INGA was established with funding from the United Nations Development Programme to the GIFT R&D and has since been funded by NORAD and the International Center for Living Aquatic Resources Management (ICLARM, now the WorldFish Center).[14] Viet Nam was a founding member of INGA in 1993 and has been an active participant in INGA activities thereafter.[15] INGA membership has provided substantial training opportunities for Vietnamese aquaculture scientists.[16] It has also facilitated exchange of scientific information and fish germplasm with other members.[17]

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[13] Source: Research Institute for Aquaculture No. 1, Bac Ninh.

[14] http://www.worldfishcenter.org/inga/

[15] Thien, Tran Mai, Nguyen Cong Dan, and Pham Anh Tuan. 2001. Review of Fish Genetics and Breeding Research in Vietnam. In Fish Genetics Research in Member Countries and Institutions of the International Network on Genetics in Aquaculture, edited by Modadugu Gupta and Belen Acosta. *ICLARM Conference Proceedings* 64. p. 91–96. Manila.

[16] Vietnamese scientists participated in quantitative genetics training, organized by INGA, in India and Thailand. RIA No. 1, Bac Ninh, Hanoi, hosted molecular genetics training, organized by INGA, for scientists from the PRC, Egypt, Thailand, and Indonesia.

[17] Viet Nam participated in INGA international meetings in India (1995), Egypt (1996), Malaysia (1999), and Bangladesh (2003), and hosted the 2001 meeting. Through INGA, Viet Nam provided common carp germplasm from RIA No. 1 to government researchers in Bangladesh, India, and Thailand and, in addition to GIFT, received germplasm of Indian major carps from India and common carp from Hungary.

OUTCOMES AND IMPACTS

Institutional Effects. Viet Nam has received large institutional benefits from its participation in DEGITA and membership in INGA. The most important of these has been the enhanced capacity of national R&D institutions. The GIFT strains, new research protocols, and new national, regional, and international linkages have enabled Viet Nam to undertake a national tilapia breeding program, based on GIFT. The new research protocols have been adopted in undergraduate and technical training courses and applied to the selective breeding of tilapia and other farmed fish.[18] Moreover, the successful selective breeding of GIFT has encouraged Viet Nam to participate in regionwide attempts to apply the same methods and approaches to the genetic improvement of farmed carps.[19] All of these developments have contributed much to raising the awareness of public and private hatchery operators and farmers about the importance of good broodstock management and about choosing strains that perform well.

Impacts on Tilapia Production. All Vietnamese national tilapia production and economic statistics treat tilapia as a single commodity, and are not disaggregated by species and strain. There are no complete statistics for tilapia seed production and harvests, and many hatcheries and farms produce fish that have unknown or doubtful breeding histories. Therefore, it is not currently possible to quantify the exact contributions of GIFT, GIFT-derived, and other strains or hybrids to tilapia seed production in Viet Nam. GIFT have probably had little impact so far in the traditional hatcheries around Ho Chi Minh City. However, some of the more modern northern and southern tilapia hatcheries are increasingly producing sex-reversed GIFT seed (Table A5.4). The sex-reversed GIFT seed production of 39.9 million in 2003 may have amounted to 5,000 t of marketable tilapia, representing 17% of the national tilapia production of 30,000 t that year.[20] The share of GIFT and GIFT-derived in tilapia production may be expected to increase substantially. The Government of Viet

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[18] Common carp (*Cyprinus carpio*), silver barb (*Barbodes gonionotus*), and river catfish (*Pangasius hypophthalmus*).

[19] (i) TA 5711-REG: *Genetic Improvement of Carp Species in Asia*, for $1.3 million, approved on 12 December 1996, Manila;
(ii) TA 6136-REG: *Achieving Greater Food Security and Eliminating Poverty by Dissemination of Improved Carp Species to Fish Farmers*, for $950,000, approved on 11 November 2003, Manila.

[20] Assuming a survival rate of 50% from fry to harvestable fish, the estimated 39.9 million sex-reversed GIFT seed production in 2003 may support the production of 5,000 t of marketable tilapia of an average size of 250 grams.

Nam's Master Plan for aquaculture development is to distribute high-quality broodstock from the national broodstock centers for multiplication at provincial centers and further distribution to private sector hatcheries. Its plan for development of tilapia farming, 2003–2010 (footnote 5), calls for the use of "*newly developed strains of tilapia*" as well as "*selective breeding and genetic improvement... through international collaboration and government funding support.*"

Table A5.4: Production of Sex-Reversed Tilapia Fry in Viet Nam, 2003 (million)

	Production by Strain, Where Known		
Hatchery and Province	**GIFT**	**Thailand**	**Total**
Research Institute for Aquaculture No. 1, Bac Ninh	4.8	1.2	6.0
Aquacultural Research and Hatchery Production Center, An Giang	3.5	—	3.5
Do Luong Hatchery, Nghe An	—	—	2.0
Yen Ly Hatchery, Nghe An	1.9	—	1.9
Fish Seed Center, ThuaThien, Hue	—	—	0.7
Dong Son Hatchery, Thanh Hoa	—	0.7	0.7
Fish Seed Center, Hung Yen	0.2	0.2	0.4
Fish Seed Company, Son La	—	—	0.2
Fish Seed Center, Hai Phong	1.8	1.2	3.0
HaiThanh Company, Ho Chi Minh City	25.0	—	25.0
PhuHuu Company, Ho Chi Minh City	1.2	10.8[a]	12.0
VinhHung Company, Vinh Long	—	—	8.0
Fish Seed Center, DongThap	1.5	—	1.5
Total (where strains are known)	**39.9**	**14.1**	**64.9**

— = no data available by strain, GIFT = genetically improved farmed tilapia.

[a] Indicates subtotal inclusive of red tilapia.

Source: Research Institute for Aquaculture No.1.

The quantities of seed of the various strains of tilapia stocked by farmers in their ponds, cages, and rice-fish farming systems, together with the differential performance traits of these strains (especially their survival, growth, and feed conversion efficiency), determine their contributions to tilapia production. Most of the small-scale pond farmers in the Mekong and Red River deltas still stock mixed-sex tilapia seed from the traditional Ho Chi Minh City and other hatcheries that are probably mainly hybrids and Nile tilapia strains with little involvement of GIFT. However, the demand for GIFT is increasing. Tilapia cage farmers, especially those in the Mekong Delta targeting urban markets and exports, farm mainly GIFT and GIFT-derived strains, together with some red tilapia. Integrated farming

systems involving rice-shrimp-fish rotations are evolving in the Mekong Delta, with high potential for growth. The contributions of GIFT and GIFT-derived strains to national farmed tilapia production, employment, incomes, and livelihoods will undoubtedly increase because of their increasing use by public and private hatcheries, and ultimately by fish farmers.

Impacts on Fish Exports from Viet Nam. The demand in Europe and North America for tilapia fillets, whole frozen tilapia, and other tilapia value-added products is growing rapidly and Viet Nam plans to increase its exports of tilapia to compete in these markets. In 2002, tilapia exports (fillets and whole frozen fish) totaled 111 t.[21] Tilapia exports present an alternative to river catfish, which faces barriers to its former export markets in the United States following allegations of dumping. Viet Nam plans (footnote 5) to increase tilapia exports, but the overall feasibility of this has not yet been fully assessed. Tilapia are already being grown to the sizes and quality required for processing as exports, using the same intensive cage farming systems used for river catfish in the Mekong Delta. It is essential to use fast-growing strains, and it is probable that GIFT and GIFT-derived strains will contribute increasingly to tilapia exports and consequent foreign exchange earnings.

Impacts on Human Nutrition. Freshwater fish are an extremely important source of animal protein and micronutrients (vitamins and minerals) for consumers in Viet Nam, both rich and poor. Tilapia are highly nutritious and are categorized in Viet Nam as low-value freshwater species. Their average retail price in 1998–1999 was $0.66/kilogram (kg), which was more affordable than snakehead (*Channa striata*, $1.21/kg) and common carp (*Cyprinus carpio*, $0.80/kg). These prices were based on surveys of fish consumers in inland areas. Other protein substitutes were more expensive: chicken ($1.32/kg) and other meat ($1.31/kg).[22] The limited information available suggests that tilapia accounted for not more than 10% of total fish expenditure by households in some locations in northern Viet Nam, and 2% in southern Viet Nam. The main reasons are probably limited supply and unfamiliarity of consumers with tilapia. The ongoing expansion of tilapia farming and increased marketing

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[21] Ministry of Fisheries. Viet Nam.

[22] Dey, Madan Mohan, Mohammad A. Rab, Ferdinand Paraguas, Somying Piumsombun, Ramachandra Bhatta, Mohammad Ferdous Alam, and Mahfuzuddin Ahmed. 2004. Fish Consumption in Selected Asian Countries. Paper presented at the Workshop on the Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia, held at the Asian Development Bank, 17–20 March 2004, Manila, Philippines.

efforts can remedy this, with wider availability of GIFT contributing significantly.

Impacts on the Environment and Biodiversity. The introductions of Mozambique tilapia and Nile tilapia to Viet Nam in the 1970s resulted in their establishment as alien species in open fresh- and brackishwaters. Therefore, subsequent introductions of Nile tilapia, including GIFT strains, are unlikely to have caused any significant additional impacts on the natural environment and biodiversity. There are no reports of adverse environmental impacts of Nile tilapia in Viet Nam. The GIFT introductions were made under the highly precautionary policies of ICLARM. Moreover, as a member of INGA, Viet Nam follows INGA's voluntary protocols with respect to responsible movement of germplasm.

The Ministry of Fisheries promulgates and implements fish quarantine regulations in Viet Nam, with responsibility for disease screening allocated to the National Office for Fisheries Quality and Aquatic Health. RIAs have responsibility for assessment of environmental and economic impacts of fish introductions and transfers. However, these institutes currently lack resources to implement biosafety measures effectively. Illegal and unquarantined introductions of alien aquatic species are continuing, posing threats to biodiversity and to aquaculture and fisheries.

Impacts on Policy. In the late 1990s, the successes of R&D for tilapia genetics and breeding, including the attractive performance of GIFT, were largely instrumental in stimulating interest in the expansion of tilapia farming in Viet Nam. In 2002, recognizing its scope for growth and potential to contribute more to domestic fish supply and fish exports, the Government introduced policies that have raised the profile of tilapia farming and increased investments in its development. The high levels of national and external support to RIAs and national broodstock centers to breed and distribute high-quality tilapia broodstock and to establish gene banks are evidence for this.

OVERALL ASSESSMENT

After almost three decades of stagnation, tilapia farming in Viet Nam has begun to expand, contributing increasingly to national rural and urban food security and nutrition—especially in terms of the low-price freshwater farmed fish affordable by poor households—as well as to livelihoods and incomes. Tilapia farming is also emerging as a contributor to fish exports. All these developments, for which GIFT and associated enhancement ofnational capacity for R&D in tilapia

genetics and breeding were catalytic factors, are at an early stage. The choice of GIFT for a national tilapia breeding program, and the nationwide dissemination of GIFT have demonstrated to the Government and to farmers the importance of selective breeding and broodstock quality for tilapia and other farmed fish. The GIFT initiatives have also helped to change policies and to increase national and external investment in R&D for fish breeding. Viet Nam's membership in INGA is a major factor in sustaining and building on these benefits. GIFT and GIFT-derived tilapia strains are already contributing significantly to farmed tilapia production and their contributions will undoubtedly grow.

If Viet Nam had not acquired GIFT and strengthened its national aquaculture R&D capacity through DEGITA and INGA, the expansion of tilapia farming in Viet Nam would have been considerably delayed, mainly because of delayed or reduced external and national support for a selective breeding program. That program has itself catalyzed increased support for and investment in tilapia farming.

FUTURE CHALLENGES

Viet Nam seeks to diversify its fish produce for domestic supply and export. This policy favors tilapia farming but poses challenges concerning adequate preparations to meet increased demand. Substantial preparations are already being made—for example, for the national broodstock centers to provide sustainable supplies of high-quality broodstock nationwide, lessening the historical over reliance on RIA No.1. The key issues for the future are regular broodstock replenishment; disease prevention and control; supply of quality feeds; broadening extension services to disseminate GIFT and other strains; and improving access of fish farmers to financial capital, other livelihood assets, markets, and support facilities and infrastructure. Tilapia farming can contribute much more to aquaculture production in Viet Nam, and especially to fish supply to meet demand from consumers, including the poor.