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Sustainable Tilapia Farming: A Challenge to Rural Development

J.D. Toledo, B.O. Acosta, M.R.R. Eguia, R.V. Eguia and D. C. Israel

The availability of improved Nile tilapia strains is a major factor that has opened up new avenues for renewed growth in the tilapia industry especially in the rural sector. This was hailed as a positive development in the tilapia industry because it promised opportunities for improvement of the rural economy. Although this article discussed the development of tilapia aquaculture in the Philippines, other countries can learn from this experience specifically in addressing challenges related to rural development.

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In the Philippines, tilapia is the second most important fish species that is farmed to improve food security and alleviate poverty. Tilapia farming in the country dates back to the early 1950s with the introduction of the Mozambique tilapia. However, it was not until 1970s when Nile tilapia (*Oreochromis niloticus*) from Thailand and Israel was introduced into the country did the tilapia farming industry start to develop. With the introduction of better growing species, tilapia farming operations expanded and this resulted in the improvement of the country's overall tilapia production. Along with this however, was a problem which later emerged due to deterioration of genetic quality of farmed tilapia stocks. Since farmers experienced decline in tilapia production, this prompted the national, regional and international organizations to develop new improved strains of the species and associated technologies.

Status of Tilapia Aquaculture in the Philippines

Tilapia and its importance to rural development

Combating poverty, particularly in the rural sector is a serious challenge of the Philippine Government. World Bank reported that in 2003, about 11% of Filipinos lived on less than 1.00 USD/day and 40% on less than 2.00 USD/day (Anon., 2006). The problem is most acute and widespread in the country's rural areas where the incidence of poverty is 54% compared to 25% in urban areas (United Nations, 2005).

To address the above challenge, the country's Medium Term Philippine Development Plan (MTPDP) for 2004-2010 has identified the aquaculture sub-sector as one of those that will support the country's drive towards combating poverty and promoting the development of the rural economy (ADB, 2005). In line with this, the Philippine Department of Agriculture has formulated measures to achieve the desired growth in the agriculture and fisheries sectors. One of these is through farming of high priority species that include the Nile tilapia – a commodity which ranked as the second most important food fish for the country's mass domestic consumption (BFAR, 2006).

History and production trends

Tilapia farming in the Philippines began in 1950s and mainly utilized low-input backyard ponds using the Mozambique tilapia (*Oreochromis mossambicus*). This species which was introduced in the Philippines in 1950s became unpopular because of its slow growth, small size at harvest, precocious breeding and other undesirable traits. In view of these characteristics, production of tilapias during 1960s was relatively low and ranged from 70-390 mt (**Fig. 1**).

In 1970s, a faster growing tilapia species (Nile tilapia) was introduced in the country and this generated a renewed interest in tilapia farming. Subsequent to this was the development and successful application of culture technologies which resulted in widespread farming operations of tilapia (particularly in many provinces in Luzon, Philippines) and a substantial growth in the country's overall production. Tilapia aquaculture production rose from 70-390 mt in 1960s to 9,436–15,434 mt in 1980s. However, growth in overall tilapia production was nearly

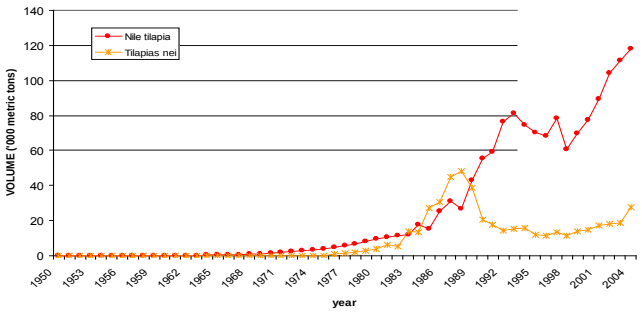

Fig. 1.Total tilapia aquaculture production (volume = '000 mt) in the Philippines, 1950-2004 (FAO, 2006)

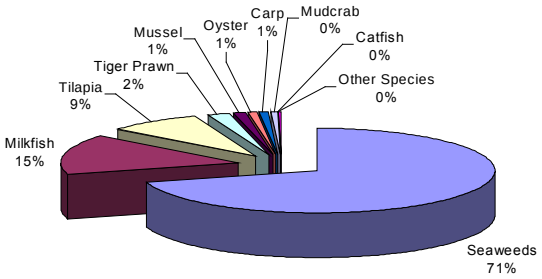

Fig. 2. Aquaculture production in the Philippines by species in 2005 (BAS, 2007)

disrupted during the 1980s when farmers experienced a decline in farm productivity due to deteriorating quality of Nile tilapia stocks.

To avert this problem and to address the emerging need of the tilapia industry, public sector R&D (by government owned, regional and international institutions) pursued the genetic improvement of locally farmed stocks through selective breeding (and other genetic improvement technologies) from 1986 to the present.

Dissemination of genetically improved Nile tilapia strains began in early 1990s and this signaled the start of a flourishing tilapia industry in the country. **Fig. 1** shows the year 1998-2004 as the period when there was accelerated growth in tilapia aquaculture and production reached its peak. With this 'boost' in production, the country emerged as the 3rd largest tilapia producer globally in 2004 (FAO, 2006). The total tilapia production during this period was 145,869 mt, a substantial change from the production during the early years of tilapia industry when it was constrained by poor genetic quality of stocks and limited supply of tilapia seeds.

In 2005, tilapia aquaculture production increased further (163,000 mt) and contributed 9.5% to Philippine aquaculture production (BAS, 2007). In terms of production by commodity (**Fig. 2**), tilapia ranked third after seaweeds (1,895,800 mt) and milkfish (289,200 mt).

Tilapia Aquaculture in the Philippines at Current Level

Availability of a wide variety of improved tilapia strains

The development of improved tilapia strains is a major factor that spurred the growth of the tilapia industry in the Philippines. At present, the following improved strains of tilapia are available for farmers to choose from: GIFT (genetically improved farmed tilapia); GST (Genomar Supreme Tilapia), FaST (FAC Selected strain of tilapia), GET-EXCEL, GMT (genetically male tilapia), and the SEAFDEC selected strain.

With the availability of improved strains and the opportunities for a better profitable margin, more farmers were encouraged to get into tilapia farming operations - both hatchery and grow-out. ADB (2005) reported that farmed tilapia production increased during the period 1981-2001 and this was mainly due to improved quality of seeds available in the market.

Commitment of public sector institutions in tilapia R&D

One of the strengths of tilapia aquaculture in the country is the presence of public R&D institutions that are continuously committed to addressing the needs of the tilapia industry. It is a known fact that the culture technologies and improved strains which are commercially available in the country are products of strong research and development cooperation among the public sector R&D institutions in the Philippines (national program institutions, regional and international research organizations based in the Philippines). The chronology of the initiatives which led to the development of improved tilapia strains (**Box 1**) indicated that for over 20 years, many institutions have been actively involved in tilapia R&D and the Philippine tilapia industry has benefited immensely from the efforts made by these institutions/ organizations (Abella, 2006).

Multi-stakeholder involvement in tilapia farming

The country's tilapia industry comprises various 'players' whose roles are crucial in the attainment of the goal as specified in the country's Master Plan for the Tilapia Industry (i.e., to increase farmed tilapia production from 122,000 mt in 2002 to 250,000 mt in 2010). Recognizing

Cage culture of tilapia in Laguna de Bay, Philippines

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the need for concerted efforts in order to meet this target, representatives from various stakeholder groups in the tilapia industry (R&D institutions, private sector, policy making bodies, feed manufacturers/suppliers, exporters, and farmers) have joined hands and established in 2003 the Philippine Tilapia, Inc. This group provides a forum for stakeholders in the tilapia industry to work together through advocacy, promotion of tilapia consumption and implementation of the tilapia industry development plan (ADB, 2005).

Strong participation of the private sector

Another notable development which has provided a big boost in tilapia farming from the latter part of 1990s to the present is the strong participation of the private sector, particularly in seed production. About 90% of the country's current tilapia seed production of about 1 billion annually comes from private sources. Private sector farmers also work hand in hand with the public sector in seed distribution, extension, financing for farm operations and setting directions for the tilapia sector (ADB, 2005). Private seed and feed suppliers advise farmers on appropriate practices as well as in improving their products and these have helped contribute to the rapid growth of the tilapia sector (Engle, 2006).

Government's support in tilapia industry

In view of the tremendous potential that tilapia could bring in terms of addressing the country's need to enhance food security, the Philippine Government strongly supports and promotes the nationwide farming of tilapia, particularly the genetically improved strain. In line with this initiative, the aquaculture sector through the Bureau of Fisheries and Aquatic Resources (BFAR) provides a greater focus on developing an improved strain (GET-EXCEL) by making this and associated culture techniques available to farmers in all regions in the Philippines, through its dissemination programs.

Strong market demand

The continuous improvement of tilapias by the public sector breeding institutions in terms of quality (e.g., improvement in size, carcass quality, etc.) has contributed to the increased demand for tilapia products in the market. Survey studies found that tilapia has become an important fish in the diet of Filipinos with the decline in the consumption of milkfish, round scad (known locally as "galunggong") and other native freshwater fishes (Edwards, 2006). Traditionally, milkfish has been the most popular and widely farmed fish in the country while round scad has also been considered as the most popular yet affordable marine fish for the poor.

Way Forward

Challenges Facing Tilapia Farming

It is projected that by 2010, the Philippine population will reach 95 million and the expected demand for fish is 2.9 million mt. In view of this, the government is faced with a greater challenge of addressing the issue of food security, particularly in terms of sustainability of fish supply. By 2025, the demand for fish in the Philippines is expected to increase to about 4.2 million mt while the estimated population is 134.9 million (Anon., 2005).

Sustaining the growth of the country's tilapia production

The country's tilapia industry master plan has targeted a 72% increase in tilapia yield by 2010. To achieve this, it is imperative that growth of tilapia production is sustained and its full potential is harnessed in order to bring benefits to the rural economy and to the country in general. The Department of Agriculture (2002) reported that with the availability of improved tilapia breeds, existing science-based, farm-verified technologies for tilapia seed production and culture, this projected increase could be attained and sustained especially if the most urgent concerns (**Box 2**) are addressed.

Bringing benefits of tilapia farming to the rural community

Apart from sustaining the country's growth of tilapia production, another big challenge for the Philippine Government is to ensure that the rural community will benefit from the tilapia industry. **Box 3** provides suggestions on how tilapia aquaculture technology could reach the rural poor communities.

Research Needs

R&D institutions have been major contributors to the country's ability to address the pressing issues affecting tilapia aquaculture and as such have been credited as primary forces that motivate growth in the tilapia industry. It is crucial that these institutions remain vigilant to developments of the country's tilapia aquaculture sector and through research, training and extension continue to address the issues affecting the industry. Apart from this, complementary policy interventions must be identified and implemented to ensure that outputs of tilapia R&D will positively impact the rural economy and the country in general.

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In view of the dynamics of tilapia industry in the Philippines, there is a need for both public and private sectors to continue working together in order to address the major challenges and attain the target indicated in the tilapia development plan. A number of research areas/initiatives have been proposed (**Box 4**) to improve tilapia production in the Philippines. These include researches in genetics, improved production techniques, marketing and credit, improved extension methodology, institutional and social aspects, nutrition and environmental impact.

Conclusion

Much is expected from the Philippine tilapia aquaculture particularly in terms of addressing the country's food security agenda. There is no doubt that tilapia aquaculture will continue to grow in terms of production. However, the main challenge of the tilapia industry is how this growth can be sustained in the long-term and in a manner that all sectors of the society particularly the rural community will benefit from.

In view of the high expectation from the tilapia aquaculture sector, the industry is now in a phase when cooperation and stronger partnerships among all the 'players' involved is crucial. The Philippine experience has revealed that if one is to address the needs of the tilapia industry, the programs of both the public and private sectors (particularly breeding and dissemination) must be in synergy or constantly in tune with the needs, requirements and capacities of the industry (Rodriguez, 2002). Parallel efforts must also be made in the formulation of policy programs and institutional mechanisms to ensure that benefits from tilapia farming and advancements in tilapia technologies will reach the small-scale farmers and the rural community.

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Box 1: Tilapia Genetic Improvement Programs in the Philippines

A decade and a half after its introduction into the Philippines, growth of Nile tilapia stocks have deteriorated as a consequence of genetic founder and bottleneck effects (Pullin and Capili, 1988), gene introgression from the less desirable Mozambique tilapia (Macaranas et al, 1986) and inbreeding (Eknath et al, 1993). Because the tilapia genetic resources used for aquaculture then had been poorly managed, genetic improvement of these limited locally farmed stocks was pursued through selective breeding programs implemented in the Philippines from 1986 up to the present.

1989: Quantitative genetics research on the Nile tilapia began when SEAFDEC and Central Luzon State University (CLSU) became members of the Aquaculture Genetics Network in Asia (AGNA), a regional network supported by IDRC of Canada. Composed of five Asian countries (China, India, Indonesia, Philippines and Thailand), AGNA was organized (in coordination with IDRC consultants from Dalhousie University) to produce: (1) a group of aquaculture geneticists in Asia; (2) a set of proven techniques for aquaculture genetic data analysis and stock improvement; and (3) genetically improved strains of fish for use in Asia (Timm, 1988; Doyle and Newkirk, 1988). With support from IDRC, SEAFDEC and CLSU worked on tilapia genetic improvement by developing statistical and experimental procedures for genetic strain evaluation, producing a salinity-tolerant strain of *O. niloticus* through hybrization with *O mossambicus* (Villegas, 1990; Basiao 2001) and enhancing growth in tilapia strains using within-family selection (Abella et al, 1990; Bolivar and Newkirk, 2002). Apart from developing standard strain evaluation procedures at SEAFDEC, a fast-growing improved stock known as FaST or FAC-selected (Freshwater Aquaculture Center-selected) tilapia was developed by CLSU researchers. First introduced in 1993, this improved breed was produced through within-family selection involving locally adapted Asian Nile tilapia strains bred through a rotational mating scheme. The genetic gain per generation for this selected stock was estimated at 12% (Bolivar and Newkirk, 2002).

1998: Two other internationally funded tilapia genetic improvement programs were implemented in the Philippines. In collaboration with BFAR, FAC-CLSU, UP-MSI and Institute for Aquaculture Research or AKVAFORSK of Norway, the World Fish Center (formerly ICLARM), conducted the Genetic Improvement of Farmed Tilapias (GIFT) project from 1988 to 1997 (Eknath et al, 1993, Bentsen et al, 1998; Gupta et al, 2001). Funded by UNDP and ADB, the GIFT project developed the GIFT Tilapia, a synthetic strain produced by crossing the best families from four Asian and four African founder stocks. Growth of this synthetic breed was enhanced through several generations of combined selection. In 1999, the GIFT Foundation inked an exclusive contract with GenoMar ASA, a private multinational company, for the commercial rights and brand name of the GIFT Super Tilapia and subsequent improved breeds that may be derived from their joint research activities (Gjoen, 2001). Presently, GenoMar has produced the GST or GenoMar Supreme Tilapia developed from the 9th generation GIFT (or G9) and further improved with the use of a DNA-based technology. Launched in late 2002, GST is believed to have 40% higher genetic gain (in terms of growth) compared to G9 (Gjoen, 2001).

Simultaneous with the GIFT program, the GMIT (Genetic Manipulation of Improved Tilapia) or YY supermale project was implemented to principally address the problems of early sexual maturation, stunting and overpopulation in tilapia culture and also to generally solve genetic deterioration in farmed tilapia strains (Mair et al, 1997). Conventional methods such as sex reversal, manual segregation of male tilapias from females and interspecific hybridization have been tried to solve overpopulation and stunting in farmed tilapias. This British ODA funded project allowed the University of Wales in Swansea, UK, FAC-CLSU and BFAR-NFFTRC to develop YY male tilapia genotypes (novel male tilapias with two male "YY" sex chromosomes instead of "XY" for normal males) through generations of feminization and progeny testing. When crossed with normal females, these YY supermales are able to sire a mean progeny sex ratio of 95% male (Mair et al, 1997). Growth of GMT tilapia was shown to be 30-50% higher than mixed sex tilapia.

1999: SEAFDEC developed its own growth-enhanced strain through a simple farm-based size-specific mass selection on previously size-graded stock. SEAFDEC-selected tilapia (SST) was developed from a domesticated Thai Nile tilapia stock called Chitralada. Response to selection after one generation of size-specific mass selection was noted at 3.2 %.

2002: BFAR introduced an improved tilapia stock known as "BFAR GET 2002 EXCEL Tilapia". Dir. Melchor Tayamen has coined the name "GET-EXCEL" which is an acronym for Genetically Enhanced Tilapia EXcellent strain that has comparable advantage over other tilapia strains for Entrepreneurial Livelihood projects in support of aquaculture for rural development". This stock was produced by combining strain crosses and adopting within family selection using the following strains: G8 or eighth generation GIFT, 13th generation FAST, Egypt and Kenya strains. The GET-EXCEL strain is purported to be 38% better in terms of growth and yield than unimproved tilapia stocks (Tayamen, 2005). This stock has been distributed by BFAR's NFFTC, central hatcheries, provincial/municipal hatcheries and/or certified/registered private hatcheries to Philippine fishfarmers through the DA-initiated project entitled "Nationwide Dissemination of GET EXCEL Tilapia" (Tayamen, 2005). The project aimed to transfer genetically improved tilapia and updated rearing technologies to resource-poor farmers through -- breeding and production, training, evaluation, and seedstock distribution cum technology demonstration.

At present, several tilapia stocks have been developed for specific environments. To promote tilapia culture in brackishwater ponds, rivers and estuaries, PCAMRD, BFAR-NIFTDC and CIRAD of France, developed a highly saline tolerant tilapia referred to as Molobicus or SaltUNO. The selection scheme involved the repeated backcrossing of progenies of *O. niloticus* and the hypersaline *Oreochromis mossambicus* (Camacho et al, 2001; Rosario et al, 2005). Another salt-tolerant hybrid, BEST or Brackishwater Enhanced Selected Tilapia was developed by BFAR-NFFTRC and FAC-CLSU. This strain was developed using three euryhaline tilapia species (*O. mossambicus*, *O. aureus* and *O. spilurus*) and three genetically improved Nile tilapia strains (GIFT, YY-supermale or GMT and FAST) as founder stocks. Meanwhile, to encourage tilapia culture in the Philippine uplands or in rural areas with relatively cooler climates, a cold-tolerant Nile tilapia stock named COLD was developed by BFAR-NFFTRC using the G8 or eighth generation GIFT and the FAST. Experimental trials have been made, however the stocks have yet to be tested commercially. The availability of these genetically enhanced stocks somehow contributed to improved yields particularly in the tilapia-producing provinces (Bulacan, Pampanga and Tarlac) near the Tilapia Science Center, Nueva Ecija, Philippines where most of these strains were developed and disseminated. Moreover, with the promotion and adoption of technologies for rearing salt-tolerant Nile tilapia strains, tilapia production from marine/brackishwater culture areas (especially in Visayas and Mindanao), have also gradually improved.

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Box 2: Most Urgent Concerns in Philippine Tilapia Production

1. maintenance of genetic integrity in improved tilapia stocks
2. sustainable production of genetically improved seedstock
3. formulation of guidelines on how to manage this new diversity (new genetically differentiated aquaculture stocks) in the context of resource conservation for aquaculture and fisheries
4. adoption of regulatory mechanisms for controlling environmental degradation caused by aquaculture activities in lakes, rivers and reservoirs where tilapia are farmed
5. creation of a coordinating body composed of public and private sector representatives that will manage and ensure the growth of the tilapia industry (the Philippine Tilapia, Inc. was established in 2003 to address this need), the challenge now is how to sustain the interest of this coordinating body

Box 3: Challenges in Expanding Tilapia Aquaculture Technology to Rural Poor Communities

Making the improved strains and associated culture technologies available to rural sector

Enhancing the access of fish farmers (especially those from rural areas, operating in small-scale and with limited resources) to improved strains of tilapia. At present, most small-scale farmers are dependent on distribution centers for improved tilapia seeds that are expensive and not sufficient to meet market demands (Basiao et al, 2005). Other farmers get their tilapia seeds from suppliers who also act as middlemen and which, in many cases, result in higher price thus making the tilapia seeds not affordable to farmers with limited capital. Another factor which influences the accessibility of farmers is the geographical location. While the present government program undertakes widespread dissemination in all regions/ provinces for GET-EXCEL, dissemination of most improved strains in the country is still largely confined in Luzon, where most tilapia producers are located (Acosta et al, 2006).

Improving the access of rural sector farmers to financial resources

One of the serious constraints of farmers in getting into tilapia farming is their lack of capital/financial resources (Sevilleja, 2006). Since the capital required to operate tilapia farming is beyond the reach of ordinary small-scale farmers, the need to formulate mechanism for financial assistance so that farmers with limited resources especially those from the rural sector can get into tilapia farming (hatchery or grow-out), is crucial. ADB (2005) reported that the Philippine Government has low interest credit and financing programs for the fisheries sector; although some programs are being channeled through commercial private and government controlled financial institutions. However, only very few farmers avail of these programs due to stringent requirements during loan application.

Enhancing the efficiency of extension system

The Philippine tilapia industry in general is still hampered by the lack of effective extension system. Despite the present efforts being made by the government in extending technical assistance to farmers, there is in general poor coordination among research institutions, local government units and farmers which negatively affects the growth of the industry. While the private sector's involvement in the dissemination of tilapia seeds can help provide the link that will facilitate the transfer of improved strain and associated culture techniques to end-users, there are issues that influence the efficiency and effectivity in their delivery to small-scale farmers (Acosta, et al 2006; Sevilleja, 2006). It is therefore necessary to strengthen institutional linkages/stakeholder involvement for the efficiency of extension services and for the greater impact of tilapia farming on rural development.

Harnessing the full commercialization of tilapia

One of the weaknesses of the Philippine tilapia industry is the lack of strategy and supportive environment for full commercialization of tilapia, particularly in the export market. While the country performs well in terms of tilapia production (i.e., it consistently ranks as one of the top 10 producing countries globally), there are factors that impede the full commercialization of this commodity. The problem is more evident for small-scale producers in the rural community who, usually, do not have the capacity to comply with the regulations and standards set by the export market. Dey and Ahmed (2005) indicated that food safety regulations, hazard analysis and critical control point (HACCP) processes, and technical barriers to trade have introduced high costs that tend to exclude the small producers and processors from the export supply chain. Apart from these, there is also lack of market information and increased competition in sales which, in many cases, result in lesser income or profit on the part of the producers. Dey and Paraguas (2001) reported that although tilapia is one of the cheapest fish in the Philippines, the price of tilapia in the Philippines is still higher than it is in international markets, making it difficult for the Filipinos to export the fish. In the Philippines, the high cost of commercial feed contributes largely to increase in the overall production cost of tilapia. Hence, another challenge is to bring down the production cost to enable the farmers to compete in the export market.

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Box 4: Suggested Research Areas/Initiatives for the Improvement of Tilapia Production

Genetics

Maintenance of the genetic integrity of improved tilapia stocks
Preliminary efforts have already been done, which should be continued, in monitoring the genetic integrity of farmed tilapia stocks (including genetically improved strains) using molecular markers and other methods.

Managing new genetically differentiated tilapia stocks

This can be done through marker-aided broodstock management schemes. With genetic marker data, appropriate broodstock management and genetic improvement methods can be formulated to protect the diversity of existing tilapia genetic resources. Thus whenever possible, DNA markers should be integrated in schemes that promote the sustainable management of farmed tilapias. Sustainable management can be achieved by both developing tilapia lines that can be utilized immediately for farming and maintaining highly genetic variable populations as valuable genetic resources for future use (Romana-Eguia and Taniguchi, 2006).

Improved Production Techniques

A study that will assess risk aspects of small-scale tilapia culture compared to other production-oriented investments should be initiated. How should risk in tilapia culture in particular and aquaculture in general, be minimized so that the poor can truly practice it?

Improved Marketing and Credit

Investigation on the impact of middlemen such as concessionaires on the profitability and economic viability of small-scale tilapia farming should be conducted. This includes searching for ways to decrease the marketing chain for tilapia ventures in order to increase the profitability from culture. In addition, a study of micro-credit and other mechanisms means of addressing the credit and finance-related aspects of small-scale tilapia culture should be pursued.

Intensify Extension

Investigation on how the country's tilapia extension aspect can be improved should be made, specifically on why extension services are weak despite government/institutions' efforts. What are the factors that impede the effective delivery of extension services to farmers, particularly in the rural sector? Is there a need for improved extension scheme? Examples of current institutional efforts on this aspect are the on-site training by BFAR, SEAFDEC/AQD, and other local agencies; publication of tilapia extension manuals written in English and translated into the vernacular.

Institutional and Social Aspects

The role of cooperatives and farmer organizations in small-scale tilapia culture should be explored. This includes a study on how small-scale tilapia growers and the poorest of the poor must be effectively organized to optimize access to production inputs, technology, credit, market opportunities (local and export) and other important components of a tilapia-based business operation. Socio-economic survey of the potential specific areas and groups of poor population who can specifically be targeted for the development of tilapia culture should be conducted. This would also include the development of untapped areas for small-scale tilapia aquaculture (e.g, lakes and other water bodies in Mindanao).

Nutrition

There is at present aggressive promotion by feed companies for the utilization of artificial feeds in fish farms especially in many provinces in Luzon. Commercial tilapia feeds are costly. Hence, less and less farmers are able to use this for their farm operations. One important area of study is to look for ways of lowering the production cost (includes the cost of inputs such as tilapia feed).

Environmental Impact

Tilapia aquaculture is a dynamic and aggressive sector in the country. With the rapid expansion and intensification of tilapia farming, it is crucial that an assessment is made on the environmental impacts of tilapia aquaculture and based on the findings, to identify and implement the necessary policy interventions.

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