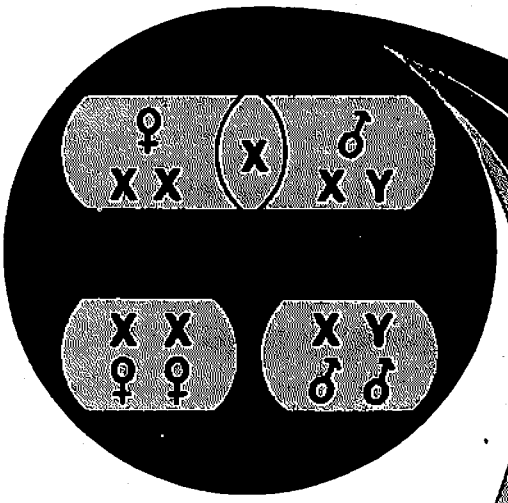
BOOK SERIES NO. 01/1989

Tilapia Genetics and Culture

Proceedings of the Seminar-Workshop
on Tilapia Genetics and Culture
FAC-CLSU, Muñoz, Nueva Ecija
20-22 June 1985



PHILIPPINE COUNCIL FOR AQUATIC
AND MARINE RESEARCH AND DEVELOPMENT
Department of Science and Technology
INTERNATIONAL CENTER FOR
LIVING AQUATIC RESOURCES
MANAGEMENT

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Foreword

The importance of the tilapias in aquaculture has been widely recognized. Over the last decade various strains of Nile tilapia have been introduced into the Philippines in the effort to enrich the genetic resources of cultured tilapias in the country. This seminar-workshop was organized to assess the progress and success of research and development programs towards this direction.

We wish to acknowledge the participants from the Central Luzon State University's Freshwater Aquacultre Center, the University of the Philippines Marine Science Institute, the UP in the Visayas-Brackish-water Aquaculture Center, the Southern Philippines Development Authority and the International Center for Living Aquatic Resources Management for their contributions to the state-of-the-art of tilapia genetics research and development in the Philippines.

The organizers wish to express their gratitude to the ICLARM for its support in the publication of this proceedings.

RAFAEL D. GUERRERO III
Executive Director

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Welcome Address

Dr. Rodolfo Arce
Director
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija

In behalf of the Freshwater Aquaculture Center, I wish to express our warm welcome to everyone. We thank you for accepting our invitation to attend this Tilapia Genetics Workshop. This occasion brings together the leading agencies and personalities involved in tilapia research, specifically in the area of tilapia genetics. Your presence here will certainly ensure the success of this workshop and of whatever program of activities you may intend to undertake.

Several years back, tilapias were practically unknown to fish consumers. To fishfarmers, they were considered as pests in fishponds especially those in brackishwater areas. Today, however, owing to technological breakthroughs, the potential of tilapias as cultured species is being recognized. The fish is profitable to culture. It has high market demands. Hence, tilapia culture offers bright economic potentials.

As the popularity of tilapia culture increased, constraints to further development and advancement of the industry were identified. One major problem identified is fingerling or seed supply. Several tilapia hatcheries are now being put up and many operators are making money out of the business. Nevertheless, the inadequacy of fingerling supply is still a felt need. Another major problem, recognized by many as having the greatest significance towards the advancement of the industry, is the deteriorating quality of our tilapia broodstock. Proof to this is the unanimous recommendation by the participants of the Philippine Tilapia Economics Workshop held in 1983 for the establishment of a National Tilapia Broodstock Center which would seek to maintain and genetically improve tilapia broodstock in the country.

We are all aware that the genetic improvement of our tilapia stock will require a lot of effort. Hybridization, selective breeding and other related work should be sustained. I personally believe, however, that this is not an impossible or a far-fetched goal. As a matter of fact, efforts are currently channeled towards improving our tilapia stock. During today's session, we shall be appraised of the progress of such activities.

I believe it is imperative to harness and pool our resources for a cooperative and concentrated effort among the various agencies we represent and the private sector to solve this problem on broodstock. Given your enthusiastic response to this call, I am sure that we will succeed. Whatever strategies we can come up for the improvement of our tilapia broodstock will help clear the way for the development of the tilapia industry, in particular, and the fishing industry in general.

Thank you and good day.

Tilapia Genetics Research at FAC: An Overview

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ABSTRACT

The Freshwater Aquaculture Center of the Central Luzon State University, in collaboration with international and national agencies, conducted studies which aimed to improve the quality of seed stock and tilapia production through genetics. Traits of three strains of Oreochromis aureus and four strains of O. niloticus were evaluated. Results of the inter- and intra-specific crosses of these strains according to performance in growth and survival, reproduction, fry production and sex distribution in various environments are discussed in this paper.

INTRODUCTION

Tilapias are now extensively cultured in the Philippines as possible source of cheap animal protein. The tilapia species grown in the country are *O. niloticus, O. mossambicus,* and *O. aureus.* Of these species, *O. niloticus* is the most suitable for culture in different production systems because of its faster growth and larger size.

Since the mid-seventies, the use of *O. niloticus* in different culture systems has shown some indications of the deterioration of the quality of stocks. Problems in size changes, age at sexual maturation and altered behavioral patterns have been observed in tilapia stocks. Thus, the Freshwater Aquaculture Center (FAC), in collaboration with national and international agencies, commenced research on the genetic improvement of tilapia.

Different species and strains/hybrids of tilapia have been evaluated at FAC but more research are still needed to produce high quality tilapia and viable stocks for higher production.

Genetic Improvement of Tilapia Broodstock

This project was spearheaded by a joint undertaking between the FAC and the Rockefeller Foundation in 1978. It was continued by FAC in collaboration with the International Center for Living Aquatic Resources Management (ICLARM) from 1979-1981. The project's primary concern was to evaluate existing stocks of tilapias in the Philippines. Three strains of *O. aureus* (Auburn- Aa, Taiwan-Ta, and Singapore- Sa, and four strains of *O. niloticus* (Philippines- Pn, Israel-Is, Singapore-Sn and Japan- Jn) were examined.

All of the *O. aureus* strains and the Singapore strain of *O. niloticus* showed sexual dimorphism. Kuo and Abella (1982) showed that the success of cross breeding depends upon the compatibility of intra- and inter-specific crosses. Both sexes of *O. aureus* from Auburn showed the highest compatibility of inter- and intra-specific hybridization.

Mass Production of Tilapia Fry

In 1982, the stocks of promising strains and hybrids of Jn, Pn, and Sn, Aa, Ta and Sa were consolidated.

The efficiency of a seed production system for *O. niloticus* (Pn x Pn) was examined under indoor and outdoor conditions. Results indicated that fry production is best under outdoor condition when sex ratio of 1:1 and a stocking density of 5 fish/m^2 are used (Kuo and Recometa, 1981). The best growth performance was exhibited by the progenies of the *O. niloticus* strains (Pn x Pn) in plastic pools and progenies of Sn x Pn in net enclosures.

The frequency of spawning varied between species, as well as between individuals of the same species or strain. There was no significant correlation among the number of fry per clutch size from the same individual.

The inter- and intra-specific crosses of Np, Ni and Aa were evaluated. The progenies of Pn x Pn cross grew faster than the In x Pn cross (Kuo, Pullin and Recometa, 1982). Inter-specific crosses of Pn, In and Aa were also evaluated for 60 days under wet and dry seasons. The progenies of Ni and Aa cross under the outdoor dry season trial gave the best growth performance. In general, growth rate was higher under outdoor conditions in both seasons (Table 1).

Table 1. Growth performance of tilapia hybrids in wet and dry seasons.

Cross + (female x male)	Condition*	Season	Culture Day 0	Culture Day 60
Pn × Aa	0	wet	13. 5 mg	515.3 mg
	i			205.3 mg
Pn × Aa	0	dry	11.13 mg	1544.2 mg
	i			352.1 mg
In × Aa	0	wet	11.5 mg	465.3 mg
	i			221.4 mg
In × Aa	0	dry	10. 7 mg	2165.0 mg
	i			333.2 mg

*Condition: 0 - outdoor, i - indoor

The growth performance of the all-male fingerlings of different genotypes were compared. The all-male progenies of the Aa x Ni cross performed best, showing evidence of heteroses in hybrids.

High Quality Tilapia Breeders

In continuation of the past work undertaken by FAC and ICLARM from 1979-1982, another project entitled "Genetic Improvement for High Quality Breeders" was conducted. The ultimate objective was to produce quality tilapia breeders through continuous selection. Under this project, F_1 and F_2 generations from *O. niloticus* (Sn) and the intra-specific crosses of Ns and Np were evaluated in ponds. Biological marking of three *O. niloticus* stocks (In, Pn and Sn) was also completed.

In 1984-85, the percentage sex distribution of the progenies of Pn x Pn, Sn x Sn, Pn x Sn, and Sn x Pn was studied. Recometa and Abella (1985) showed that the Pn x Pn and Sn x Sn progenies tend to straddle the 50% variation in sex distribution. On the contrary, the progenies of the Pn x Sn and Sn x Pn showed wide deviation producing 73.26% and 75.76% male, respectively. It is assumed that autosomes also influence sex determination.

Problems and Prospects

The pressing need to produce quality tilapia will remain to be a major area of concern of FAC. Fish culture researchers have been trying on increased spawning of tilapia strains/species based on reproductive behavior, physiology, taxonomic proximity, and the factors influencing the frequency with which two species cross.

Continuous intra- and inter- specific selection appears to be the most appropriate approach towards this end. It may take some time before success could be achieved but surely, quality fish for the tilapia industry will be produced. This, in turn, will boost the fish farming industry in producing low- cost animal protein.

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Experiences on the Culture of Tilapia Under Saline Conditions

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ABSTRACT

This paper discusses the results of experiments on the culture of Tilapia nilotica, Tilapia mossambica and red tilapia at the Brackishwater Aquaculture Center. Daily weight increment was used as a crude indicator of changes in the quality of tilapia strains over the experimental period. Evaluation showed no sufficient evidence that inbreeding between T. nilotica and T. mossambica has occurred. It is clear that studies to determine whether inbreeding has occurred are needed.

INTRODUCTION

The efforts that have been directed towards tilapia culture indicate that the world has realized the importance of tilapia as a food fish. However, some producers of tilapia seeds practice continuous inbreeding which could cause the deterioration of quality of tilapia strains in the Philippines and the decline of the acceptability of tilapia as culture species.

Many factors contribute to the deterioration of tilapia strains in the Philippines. These include: suppliers lack of technical knowledge on the genetics of tilapia fingerlings; lack of understanding of genetics as a tool in hatchery operations; poor broodstock management, and; use of wild stocks in hatcheries.

This paper attempts to evaluate the effects of the above-mentioned factors based on the results of experiments on the culture of tilapia at the Brackishwater Aquaculture Center.

Daily weight increment was used as a crude indicator of changes in the quality of tilapia strain. In order to determine such changes, the weight increment of the fish was examined at various stocking densities, level of management and species used.

Tilapia mossambica

It has been recognized that the culture of local tilapia species can be unsatisfactory because of inbreeding depression in stocks due to the small number of progenitors (Wolfarth and Hulata, 1981). This was observed in Java and there are strong indications that such can happen to *T. mossambica* in the Philippines.

Table 1 shows the daily weight gain of *T. mossambica* at varying stocking densities and level of management under brackishwater or saline conditions (salinity range 12-43‰).

Table 1. Daily weight increment of *Tilapia mossambica* at varying stocking densities and level of management under brackishwater conditions.

Daily weight increment (g)	Density (No./ha)	Level of management	Source of stock	Author/year
1.0-1.1	4,000	fertilization, monoculture (all-male)	Ponds and canals of BAC	Fortes, 1975;1976
1.37-1.98	4,000	fermented pig manure as fertilizer; monoculture (all-male)	-do-	Laureta, 1982
0.33-0.49	5,000	fertilization; polyculture w/ tenpounder (mixed-sexes)	-do-	Fortes, 1979
0.30-0.51	5,000	fertilization; polyculture w/tarpon (mixed-sexes)	-do-	Fortes, 1980
0.22	22,000	fertilization; polyculture w/ seabass (mixed-sexes)	-do-	Fortes, Genodepa and Da-anton, 1985
0.22	22,500	fertilization; monoculture (mixed-sexes)	-do-	-do-

Daily weight gain of all male *T. mossambica* was higher in ponds fertilized with fermented pig manure than in ponds fertilized with inorganic fertilizers at a density of 4,000/ha.

Daily weight increment dropped to 0.30-0.51 g/day in mixed sex populations with tarpon *(Megalops cyprinoides)* or ten-pounder *(Elops hawaienensis)* as biological control.

Weight gain did not differ in the monoculture and polyculture of *T. mossambica* at 22,500/ha.

The results gave no indication that *T. mossambica* has suffered from inbreeding depression. Decreases in weight gain seem to have been influenced primarily by stocking density and possibly by the slow growth of the female tilapia in mixed sex stocks.

However, unpublished information indicate that *T. mossambica* introduced in the Philippines in 1950 was bigger than the stocks available now.

Tilapia nilotica

Table 2 shows the daily weight gain of *T. nilotica* at a stocking density of 10,000/ha and under different levels of management. Results revealed that *T. nilotica* responds favorably to supplemental feeding and fertilization. Growth rate increased as the level of management was intensified.

It is possible that hybridization has occurred between *T.nilotica* and *T mossambica* depending upon the source of stock.

In most cases, *T. nilotica* broodstock are maintained by fish farmers in ponds which are not secured adequately against intrusion of *T. mossambica.*

The cross of *T. mossambica* x *T. nilotica* gave hybrids of better survival, feed conversion rate and growth than the parents (Avault and Shell, 1968).

Table 2. Daily weight increment of *Tilapia nilotica* (mixed-sex) at varying densities and level of management under brackishwater conditions.

Daily weight increment (g)	Density (No./ha)	Level of management	Source of stock	Author/year
0.43-1.32	10,000	supplemental feeding	CLSU	Corre, 1980
0.95-0.96	10,000	-do-	Iloilo	Corre, Tubongbanua and Sanchez, 1982
1.25	10,000	-do-	Negros Occidental	Woessner and Fortes, 1984
0.40	10,000	fertilization 16-20-0	Iloilo	Corre, Tubongbanua and Sanchez, 1982
0.81	10,000	organic fertilization	-do-	-do-
0.63	10,000	chicken manure plus 16-20-0	-do-	-do-
1.15	10,000	chicken manure plus feed	-do-	-do-
1.35	10,000	chicken manure plus feed plus 16-20-0	-do-	-do-

Red Tilapia

Table 3 shows that as stocking density is increased from 10,000/ha to 40,000/ha, daily weight gain of red tilapia decreased but not significantly.

Table 3. Daily weight increment of red tilapia at varying stocking densities

Daily weight increment (g)	Density (No./ha)	Level of management	Source of stock	Author/year
1.40	10,000	Supplemental feeding	TRCF, Sucat Paranaque Rizal	Corre and Sanchez, 1984
0.98	20,000	-do-	-do-	-do-
0.82	30,000	-do-	-do-	-do-
0.71	40,000	-do-	-do-	-do-

In general, the values were not significantly different from those obtained with *T. nilotica*.

Electrophoretic analysis revealed that the red or colored tilapia used in the studies was an admixture of *T. nilotica* and *T. mossambica*. However, the frequency of *T. mossambica* allele is higher. Electrophoresis further suggested that the heterozygosity of the colored tilapia was higher than the *T. nilotica* used in the studies.

REMARKS

The observations and experiences presented in this paper are not sufficient to determine whether or not the species of tilapia used in the experiments have suffered from inbreeding depression. The results imply that studies specific to this purpose should be further conducted. Such studies should be directed ultimately to the production of "certified" tilapia seeds.

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Tilapia Genetic Resources in Asia, with Special Reference to Future Tilapia Culture R & D in the Philippines

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ABSTRACT

It is well established that tilapia is commanding increasing interest as a cultured fish throughout the tropics, and that the Philippine tilapia culture industry is in a phase of explosive growth. Any effort within the Philippines to improve the culture performance of tilapias will depend, to a large extent upon the genetic resources available. This review summarizes the tilapia genetic resources of Asian countries and discusses these resources in relation to future research and development activities in the Philippines. The principal species considered are Oreochromis aureus, O. mossambicus, O. niloticus and Tilapia rendalli.

Tilapias Present in Asia

The most comprehensive summary of tilapia introduction to, and transfers within, Asia up to 1980 is that of Welcomme (1981). However, his list is not exhaustive since many unrecorded transfers have undoubtedly been made. Guerrero (1985) has also summarized tilapia introductions to the Philippines. Table 1 combines their records with additional unpublished information. Not included in the table are records of introductions of species of marginal interest for contemporary aquaculture (e.g. *Oreochromis urolepsis hornorum* and its hybrids, and *Tilapia zillii*). *Oreochromis spilurus*, a Kenyan species developed recently for mariculture in Kuwait (Hopkins, 1983) is likewise not included in the table. This species has not yet been used outside Africa and the Middle East. The possible environmental consequences of its transfer should be considered first before it could actually be introduced to the country. This species thrives and reproduces in seawater.

Table 1. Introduction to and transfers within Asia of the most important tilapias used in or affecting aquacultural operations.

To	From	Date(s)	Status
A. *Oreochromis aureus*[a]			
Philippines	Auburn, USA (origin, Israel)	1977	Limited stocks held at Central Luzon State University (CLSU); some show spinal deformity
Philippines	Singapore (origin, Israel)	1977	Introduction by the Philippine Bureau of Fisheries & Aquatic Resources (BFAR); current status unclear
Philippines	Singapore (origin, Israel)	1978	Introduction by SEAFDEC; current status unclear
Philippines	Israel	1982	Introduction of Ein Hamifratz strain for all male hybrid production by Crust Asian Resources Inc.; current status unclear
Philippines	Taiwan	1984	Introduction by BFAR/ICLARM for study purposes; now building up stocks
Taiwan	Israel	1963, 1966, 1974	Very important in aquaculture (Li and Liao, 1979)
B. *Oreochromis mossambicus*[b]			
Bangladesh	Thailand	1954	Used in aquaculture but populations unstable
China (People's Republic)	Vietnam	1957	Widespread in culture ponds and natural waters in southern China
Hong Kong	Singapore and Thailand	ca./ 1940's	Widespread in pond and reservoirs

[a] Not well-established in Philippine water as was previously suggested by Welcomme (1981).

[b] Anecdotal reports suggest the possibility of pre 1950 introductions to Mindanao, Philippines; if true, the source was probably Indonesia. Atz (1954) also mentioned introductions to Malaysia, Taiwan, Molucca Islands, Indonesia and Pakistan.

Table 1. Continued

To	From	Date(s)	Status
India	Thailand	1952	Well established in fresh and brackishwaters; a nuisance in culture ponds
Indonesia	Africa,? source	1939	Well established; a prolific breeder competing with more favored cultured species
Korea	Thailand,	1953	Held in experimental intensive culture systems; low winter temperatures prevent year-round outdoor culture
Malaysia	Indonesia	1941-1945	Self-breeding populations in ponds; breeds profusely and is not highly regarded by consumers
Papua New Guinea	Malaysia	1954	Widespread and important onwards in capture fisheries
Philippines[b]	Thailand (assume origin Indonesia from early African introduction, see below)	1950	Introduction of nine fish by BFAR; now widespread in natural fresh and brackish waters and a considerable nuisance in culture ponds
Sri Lanka	?	1945-1948	very abundant; important in reservoir fisheries; has interbred with *O. niloticus* in culture systems
Thailand	Malaysia	1949	Well established from 1950-60, but populations have since declined; a nuisance in brackishwater culture ponds, but no evidence with cultured *O. mossambicus* in freshwater in Central Thailand

[b] Anecdotal reports suggest the possibility of pre 1950 introductions to Mindanao, Philippines; if true, the source was probably Indonesia. Atz (1954) also mentioned introduction to Malaysia, Taiwan, Molucca Islands, Indonesia and Pakistan.

Table 1. Continued

To	From	Date(s)	Status
C. *Oreochromis niloticus*[c]			
Bangladesh	Thailand	1974	Widespread and useful for aquaculture
China	Africa	1978	Cultured in Hubei Province
Hong Kong	Taiwan	1972	Widespread in fish ponds; interbreeds with *O. mossambicus*
Indonesia	Taiwan	1969	Fast growing and useful in aquaculture
Philippines	Israel (Uganda strain)	1972	Introduction by the Laguna Lake Development Authority; current status unclear
Philippines	Thailand (origin, Egypt)	1972	Introduced by BFAR; current status unclear
Philippines	Israel (Ghana strain)	1979	Introduced by ICLARM; current stocks still available
Philippines	Singapore (origin, Israel Ghana strain)	1979	Introduced by SEAFDEC; stocks still available
Philippines	Israel	1982	Introduction of Ein Hamifratz strain for all -male hybrid production by Crust Asian Resources Inc.; current status unclear
Philippines	Taiwan	1984	Introduction by BFAR/ICLARM for study purposes; now building up stocks
Sri Lanka	Israel	Late 1970s	Potentially useful for aquaculture but populations are interbreeding with *O. mossambicus*

[c] Most Asian *O. niloticus* populations face the prospect of introgressive hybridization with *O. mossambicus* and this has already occurred to a considerable extent in the Philippines, as demonstrated by electrophoretic analyses (Taniguchi *et al.*, 1985) and in Sri Lanka, based on visual observations by the author. Thai populations appear to have interbreed very little with *O. mossambicus*, but may in future interbreed with tilapias rejected from red tilapia culture operations because of their normal or incomplete red coloration.

Table 1. Continued

To	From	Date(s)	Status
Thailand	Japan	1965	Well established and widely cultured; the 'Chitralada' strain
Thailand	Israel	1983	Under study at the National Inland Fisheries Institute, Bangkok
Vietnam	?	?	Widespread in lakes; current status unclear
D. *Tilapia rendalli*[d]			
Sri Lanka (origin)	Malaysia	1969	Important in reservoir fisheries
Thailand	Belgium (origin Zaire?)	1955	Poorly established; current status unclear
E. *Red tilapia*[e]			
Indonesia, Korea, Philippines	Principally Taiwan and the USA	1979-85	Numerous institutional and private sector introductions reflecting the increasing interest in red tilapia culture; the identity and status of many populations are unclear

[d]Also introduced into Malaysia and Vietnam (Jhingran and Gopalakrishnan, 1974) but current status of *T. rendalli* populations unclear; a herbivorous species superior to *T. zillii* for culture (R.S.V. Pullin, unpublished manuscript).

[e]All red tilapias investigated in Asia are hybrids; most are *O. niloticus* x *O. mossambicus*, but some may involve other species such as *O. aureus* (Galman and Avtallion, 1983; Liao and Chang, 1983)

Source: Welcomme (1981); Guerrero (in press): Pullin, R.S.V. (unpublished data); and other sources cited.

From Table 1, the following can be concluded:

- For *O. aureus*, genetic resources are poor throughout Asia.
- *O. mossambicus* is a widespread nuisance and interbreeds with some cultured *O. niloticus* populations.
- *T. rendalli* is not readily available for use in Asian aquaculture except in Sri Lanka; and the performance of the Sri Lankan fish in managed aquaculture rather than reservoir stocking is not documented.
- The identity and status of most Asian red tilapia populations are unclear.

Asian Tilapia Genetic Resources and Future R & D

It is clearly undesirable that Asian countries should have to rely on limited genetic resources for the future improvement of tilapia culture performance. There can be danger in the introduction of new exotic fish species, which, later, could escape from culture installations and become established in natural waters. One example is the past bad experiences with *O. mossambicus* introductions. For *O. niloticus*, however, its culture performance is well-proven worldwide (Pullin, 1985). Hence, it is advisable for countries already using this species to introduce the best cultured strains available, to assess their performance, and to use promising strains in new breeding programs. All new introductions must be quarantined to guard against the risk of spreading disease. Existing populations are, of course, already adapted to their local environments but their culture performance may be unreliable because of the various problems mentioned.

One difficult constraint in the improvement of tilapia culture performance is the dearth of sources of broodstock for new introduction Pullin (1983) suggests Israel, Taiwan and Africa (e.g., Lake Manzallah, Egypt) as the only reliable sources for *O. aureus* and *O. niloticus*. To these may be added the Chitralada strain of *O. niloticus* from Central Thailand. However, only the Israeli *O. niloticus* and *O. aureus* populations are being checked regularly by electrophoresis. Some Taiwanese and Thai *O. niloticus* populations may also be affected by introgressive hybridization. Therefore, no new fish should be introduced without full documentation of their geneology and morphometric and electrophoretic confirmation of their identity.

For future research and development work in the Philippines, it would be useful to introduce *O. aureus* from Israeli and/or African sources to supplement existing genetic resources and assess the culture prospects for this species. *O. aureus* has good cold tolerance for upland aquaculture. Additional Israel and/or African introductions of *O. niloticus* could broaden the genetic base of this species which is considered the most important cultured tilapia in the tropics. It would likewise be useful for the Philippines to introduce the *O. niloticus* Chitralada strain from Thailand, since the Thai climate and culture systems are broadly similar to those of the Philippines. The excellent culture characteristics of this strain may be reproducible, although the founder stock introduced to Thailand (50 fish) was small. The introduction of *T. rendalli* (e.g., from Zimbabwe) would enable the initiation of research on herbivorous tilapia culture. Further introductions of red tilapias are probably undesirable until their genetic characteristics are sufficiently documented. Commercial claims for heritability of color and culture performance should be treated with

caution. The Ein Hamifratz hatchery in Israel is currently developing a pure red strain of *O. niloticus*, but details of its performance are not yet available (D. Mires, pers. comm.).

Finally, for any future introductions, it is essential to avoid the mistakes of the past. A founder stock of at least 2,000 fingerlings should be acquired and reference collections established in which the populations should never fall below 50 breeding pairs.

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Genetic Characterization of Cultured Philippine Tilapia Stocks

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ABSTRACT

Tilapia raising is now a flourishing industry in the Philippines. While the principal species farmed is assumed to be O. niloticus, widespread interbreeding between the culture species and the less desirable species O. mossambicus occurs. Morphological and meristic characters used for taxonomic identification can be limiting in that hybrids do not exhibit intermediate morphological characters.

Electrophoretic techniques were utilized to analyze existing tilapia populations in the country as well as from two other Asian countries. Among 21 loci investigated, nine were found to be polymorphic. Of the nine polymorphic loci, six were found to be divergent between O. niloticus and O. mossambicus namely Gpi-1, Mdh-1, Sod, Sdh, Mp-2 and Mp3. At these loci, O. mossambicus displays a different and fixed allele. This is expressed in appreciable frequency in the Philipine O. niloticus populations.

INTRODUCTION

Many incidence of hybridization among related species of tilapia are known to occur in natural water bodies (McAndrew and Majumdar, 1983). Poor broodstock management practices also allow widespread interbreeding between the cultured stock *O. niloticus* and the less desirable species *O. mossambicus*. Thus, due to widespread introduction of tilapia species and the ease of hybridization, it now becomes difficult to exactly identify the species through morphological characters.

While fish culturists assume that the species they are raising is the Nile tilapia, it is highly probable that hybridization between the cultured stock and the wild stock has occurred. Morphological and meristic characters used in taxonomic identification can be limiting in that hybrids do not exhibit intermediate morphological characters.

Electrophoretic methods which use the migration of proteins in an electric field to detect differences in their charge and shape provided a useful tool to identify the species and their hybrids. Several authors have used electrophoretic techniques for species identification of tilapia (Avtalion, 1982; Basiao and Taniguchi, 1984; Macaranas *et al.*, 1985; and Taniguchi *et al.* 1985).

The objective of this study was to genetically charaterize tilapia species and their hybrids and to standardize techniques for monitoring broodstock.

MATERIALS AND METHODS

Tilapia populations were sampled from various sources (Table 1). *O. niloticus* and *O. mossambicus* were identified based on the characters described by Trewavas (1983).

Table 1. Details of Tilapia populations sampled (see Table 3).

Population	Number of samples	Location	Remarks
Oreochromis niloticus			
1	20	Laguna Province, Philippines	Private farm ponds
2	16	Laguna Province, Philippines	Private farm ponds
3	20	Rizal Province, Philippines	Private farm ponds
4	20	Laguna Province, Philippines	Private farm ponds
5	20	Rizal Province, Philippines	Private farm ponds
6	29	Laguna Province, Philippines	Private cage farm
7	40	Laguna Province, Philippines	Private cage farm in crater lake
8	20	Binangonan, Rizal Province, Philippines	Research Station
9	17	Iloilo Province, Visayas, Philippines	Research Station
10	34	Buluan, Maguindanao Province Mindanao, Philippines	Government ponds
11	19	Sultan Kudarat Province, Mindanao, Philippines	Government ponds
12	19	Southern Taiwan	Research Station
13	20	Pathum Thani Province Thailand	Research Station
Oreochromis mossambicus			
1	40	Pangasinan Province, Philippines	Private coastal milkfish ponds
2	40	Pangasinan Province, Philippines	Private coastal milkfish ponds
3	40	Bulacan Province, Philippines	Private farm ponds

Table 1. Continued.

Population	Number of samples	Location	Remarks
4	20	Malabon, Metro Manila, Philippines	Private farm ponds
5	20	Malabon, Metro Manila, Philippines	Market, caught in natural waters

Sample Preparation and Electrophoretic Analysis. Crude extracts from eye, liver, heart and muscle tissues were prepared and analyzed using starch gel electrophoresis and isoelectrifocusing gels, and were stained for 21 protein loci as previously described (Macaranas *et al.*, 1985). Table 2 presents a list of enzymes and proteins investigated, number of loci, alleles with their relative mobilities and tissues examined.

Table 2. List of enzymes and proteins investigated, E.C. number locus, alleles with their relative mobility (Rm), and tissues examined in sample of *O. niloticus* and *O. mossambicus*.

Enzymes and Proteins NS	EC No.	Locus	Allele	Rm	Tissue
Alcohol dehydrogenase (ADH)	1.1.1.1	*Adh*	A	83	Liver
			B	100	
			C	120	
Asparate aminotransferase (AAT)	2.6.1.1.	*Aat-1*	A	100	Liver
			B	46	
		Aat-2			Muscle
Esterase (EST)	3.1.1.3	*Est*	A	105	Eye
			B	100	
Glucose phosphate isomerase (GPI)	5.3.1.9	*Gpi-1*	A	120	Heart
			B	100	
		Gpi-2			Muscle
Isocitrate dehydrogenase (IDH)	1.1.1.42	*Idh*			Muscle
Lactate dehydrogenase (LDH)	1.1.1.27	*Ldh-1*			Eye
		Ldh-2			Heart
		Ldh-3			Muscle
Malate dehydrogenase (MDH)	1.1.1.37	*Mdh-1*	A	120	Muscle
			B	100	
		Mdh-2			Heart/Muscle
		Mdh-3			Heart/Muscle
		Mdh-4			Heart/Muscle
6-Phosphogluconate dehy drogenase (6-PDG)	1.1.1.44	*6Pgd*			Liver
Phosphoglucomutase (PGM)	2.7.5.1	*Pgm*			Eye
Sorbitol dehydrogenase (SDH)	1.1.1.14	*Sdh*	A	133	Liver
			B	100	

Table 2. Continued

Superoxide dismutase (SOD)	1.15.1.1.	*Sod* A	100	Liver
		Sod B	25	
Muscle protein (MP)		*Mp-1*		Muscle
		Mp-2 A	100	Muscle
		Mp-2 B	80	
		Mp-3 A	100	Muscle
		Mp-3 B	80	
TOTAL	12		21	

RESULTS AND DISCUSSION

Initial evidence of hybridization between *O. niloticus* and *O. mossambicus* was provided by two electrophoretic markers, Glucose phosphate isomerase (Gpi) and muscle parvalbumin (Mp). Gpi is an isozyme that is controlled by two loci in tilapia. One locus has the same allele of character for both *O. niloticus* and *O. mossambicus*, but the other locus, Gpi-1, has different alleles in each species. Hybrids were observed to display both alleles. Acidic muscle proteins called parvalbumins which were separated by isoelectric focusing stain at two loci in tilapia. The upper locus is fixed for both *O. niloticus* and *O. mossambicus* species while the lower locus has a different allele for each. Hybrids were observed to have both alleles in contaminated stocks.

A more extensive collection of tilapia populations from different culture systems was made and more protein loci were investigated to identify species specific alleles. Two *O. niloticus* populations from Taiwan and Thailand provided as reference samples for *O. niloticus* species.

Twelve enzymes and proteins were examined giving a total of 21 loci resolved. Twelve loci fixed for the same allele for both species while 9 were polymorphic. The diagrams of the different allelic expressions at the 21 protein loci are shown for both *O. niloticus* and *O. mossambicus* in Fig. 1. Alleles at each locus are consistent with the known sub-unit structures of the enzymes, three-banded for dimers and two-banded for monomers. Heterozygous Sorbitol dehydrogenase (Sdh) genotype showed a diffused and broad band which is probably a poorly resolved 5-banded phenotype.

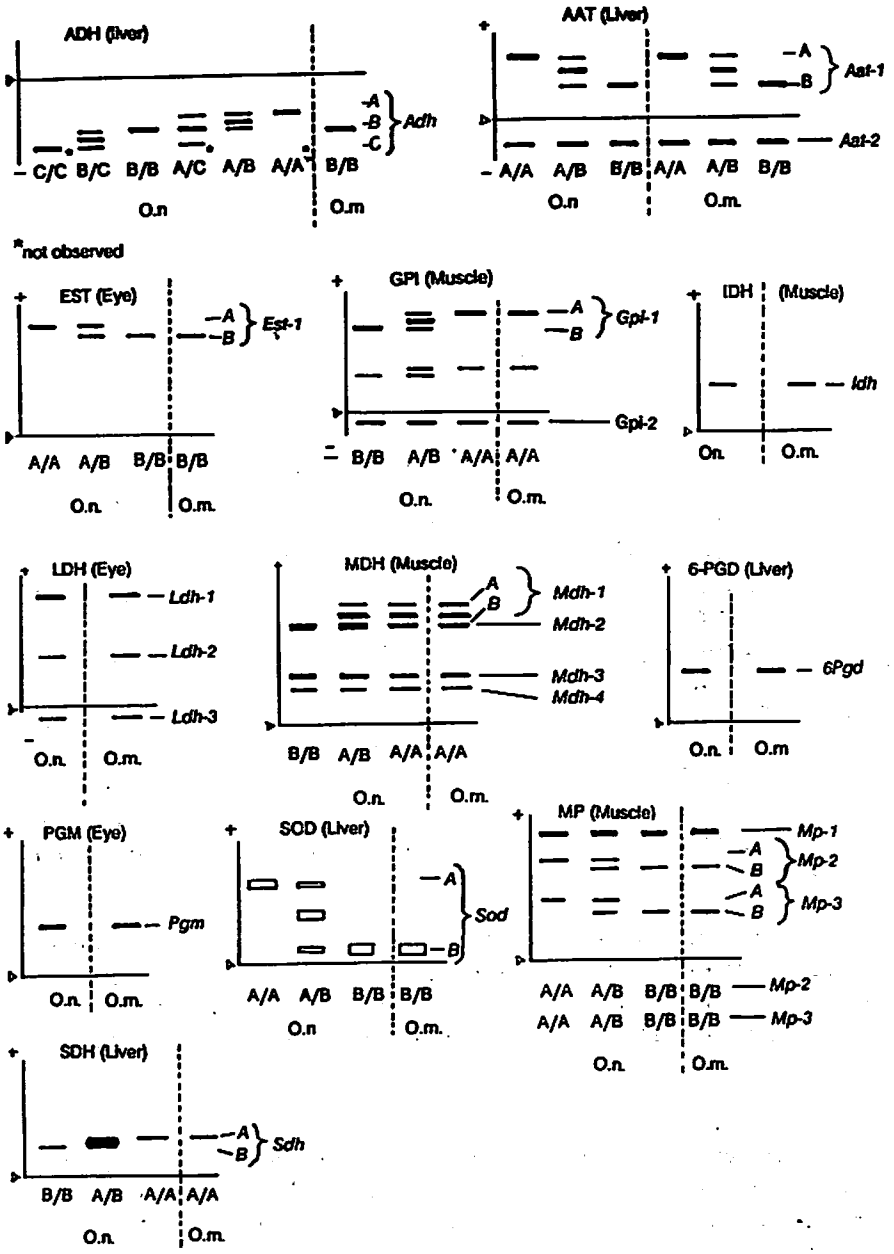

Figure 1. Allelic expressions at 21 protein loci in *O. niloticus* and *O. mossambicus* populations.

Gene frequencies for the 21 protein loci is presented in Table 3. The value of 1.00 denotes a fixed allele. Of the 21 loci, 12 were fixed for the same allele for both species while 9 were polymorphic. The low variability in *O. mossambicus* populations is indicated by a single polymorphic locus, Aspartate amonotransferase (Aat-1), while very high variability at the polymorphic loci is observed in Philippine *O. niloticus* populations. Of the 9 polymorphic loci, 6 were found to be divergent between *O. niloticus* and *O. mossambicus*, namely Gpi-1, Mdh-1,Sod, Sdh, Mp-2, and Mp-3. At these loci, *O. mossambicus* displays a different and fixed allele and this is expressed in appreciable frequency in Philippine *O. niloticus* populations. This is the biochemical evidence that established the extensive introgressive hybridization of *O. mossambicus* genes into Philippine *O. niloticus* genes.

Although Adh, Aat-1 and Est loci were polymorphic, they were not found to be divergent between *O. niloticus* and *O. mossambicus*.

Nei's genetic distance (1972) was utilized to compare the *O. niloticus* populations from *O. mossambicus* populations. Genetic distance was calculated for pair wise comparisons and are summarized in Table 4. Group comparisons are given in means ± standard error in the right side of the matrix. The five *O. mossambicus* populations are characterized by minimal genetic distance values ranging from 0 to 0.0040. *O. niloticus* populations on the other hand, displayed an array of values ranging from a low 0.0005 between populations 1 and 2 to a high value of 0.0478 between populations 11 and 12. Comparisons between *O. mossambicus* and *O. niloticus* populations gave an average value of 0.2660 ± .0072. Philippine *O. niloticus* populations with an average D of 0.0055 are significantly different from Taiwan and Thailand populations which have an average D value of 0.0166. Philippine *O. niloticus* is further characterized by a lesser average D value from *O. mossambicus* which is 0.2483 as compared to Taiwan and Thailand *O. niloticus* with an average D of 0.3631.

Estimates of *O. mossambicus* introgression were made from frequencies of the secondary allele at the six divergent loci (Gpi-1, Mdh-1, Sdh, Sod, Mp-2 and Mp-3) in the 13 *O. niloticus* populations (Table 5). The most introgressed population (11) (about 30% *O. mossambicus* mean frequency) was from a government hatchery in Mindanao. Whether the minimal frequencies of the secondary allele in Taiwan and Thailand populations were due to introgression is uncertain. McAndrew (1981) observed the *O. mossambicus* allele of the adenosine deaminase locus in two *O. niloticus* individuals from Thailand but evidence of introgression was doubtful.

Table 3. Gene frequecies at 21 protein loci in *Oreochromis niloticus* and *O. massambicus* populations (for details of locations -see Table 2).

Locus / Allele	*O. niloticus*													*O. massambicus*					
	Philippines											Taiwan	Thailand	Philippines					
	Luzon								Visayas	Mindanao				Luzon					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	1	2	3	4	5	
Adh A	0	0	0	0	0	0	0	0	0	0.015	0.029	0	0	0	0	0	0	0	
Adh B	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.985	0.971	0.321	1.000	1.000	1.000	1.000	1.000	1.000	
Adh C	0	0	0	0	0	0	0	0	0	0	0	0.179	0	0	0	0	0	0	
Aat-1 A	0.975	0.969	0.875	0.950	1.000	0.983	0.957	0.850	0.853	0.941	-	1.000	1.000	0.550	0.538	0.462	0.525	0.750	
Aat-1 B	0.025	0.031	0.125	0.050	0	0.017	0.043	0.050	0.147	0.059	-	0	0	0.450	0.462	0.538	0.475	0.250	
Aat-2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Est A	0.075	0.031	0.050	0.150	0.125	0.138	0.075	0.050	0.176	0	0	0.575	0.975	0	0	0	0	0	
Est B	0.925	0.969	0.950	0.850	0.875	0.862	0.925	0.950	0.824	1.000	1.000	0.425	0.025	1.000	1.000	1.000	1.000	1.000	
Gpi-1 A	0.250	0.250	0.150	0.125	0.075	0.172	0.338	0.225	0.206	0.162	0.132	0.025	0	1.000	1.000	1.000	1.000	1.000	
Gpi-1 B	0.750	0.750	0.850	0.875	0.925	0.828	0.662	0.775	0.794	0.838	0.868	0.975	1.000	0	0	0	0	0	
Gpi-2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Idh	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Ldh-1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Ldh-2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Ldh-2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Mdh-1 A	0.100	0.125	0.175	0.275	0.100	0.121	0.112	0.250	0.206	0.294	0.500	0.050	0	1.000	1.000	1.000	1.000	1.000	
Mdh-1 B	0.900	0.875	0.825	0.725	0.900	0.879	0.888	0.750	0.794	0.706	0.500	0.950	1.000	0	0	0	0	0.975	
Mdh-2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Mdh-3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Mdh-4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Pgm	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
6Pgd	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Sdh A	0.125	0.094	0.275	0.075	0.125	0.121	0.125	0.125	0.294	0.217	0.267	0	0.025	1.000	1.000	1.000	1.000	1.000	
Sdh B	0.875	0.906	0.725	0.925	0.875	0.879	0.875	0.875	0.706	0.783	0.733	1.000	0.975	0	0	0	0	0	
Sod A	0.950	0.875	0.950	0.850	0.975	0.966	0.938	0.900	0.824	0.818	-	1.000	0.950	0	0	0	0	0	
Sod B	0.050	0.125	0.050	0.150	0.025	0.034	0.062	0.100	0.176	0.182	-	0	0.050	1.000	1.000	1.000	1.000	1.000	
Mp-1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Mp-2 A	0.950	0.938	0.775	0.825	1.000	0.966	0.913	0.850	0.912	0.706	0.711	1.000	1.000	0	0	0	0	0	
Mp-2 B	0.050	0.062	0.225	0.175	0	0.034	0.088	0.150	0.088	0.294	0.289	0	0	1.000	1.000	1.000	1.000	1.000	
Mp-3 A	0.875	0.906	0.875	0.900	0.925	0.793	0.925	0.850	0.794	0.706	0.684	1.000	1.000	0	0	0	0	0	
Mp-3 B	0.125	0.094	0.125	0.100	0.075	0.207	0.075	0.150	0.206	0.294	0.316	0	0	1.000	1.000	1.000	1.000	1.000	

Table 4. Matrix of genetic distance (Nei, 1972) within and between tilapia populations: *Oreochromis niloticus* and *O. mossambicus*.

		O. niloticus												*O. mossambicus*				
		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	1	2	3	4	5
O. niloticus	①																		
	②	.0005																	
	③	.0044	.0041																
	④	.0041	.0033	.0036															
	⑤	.0019	.0027	.0059	.0041														
	⑥	.0009	.0020	.0052	.0037	.0013													
	⑦	.0006	.0008	.0050	.0049	.0040	.0027												
	⑧	.0018	.0014	.0025	.0015	.0041	.0025	.0022											
	⑨	.0044	.0048	.00024	.0046	.0059	.0039	.0053	.0035										
	⑩	.0084	.0076	.0031	.0050	.0114	.0080	.0094	.0033	.0056									
	⑪	.0168	.0162	.0088	.0098	.0191	.0151	.0183	.0081	.0104	.0027								
	⑫	.0188	.0214	.0265	.0174	.0131	.0156	.0212	.0234	.0221	.0358	.0478							
	⑬	.0046	.0047	.0095	.0069	.0015	.0046	.0071	.0080	.0116	.0165	.0279	.0141						
O. mossambicus	1	.2793	.2727	.2340	.2594	.3132	.2826	.2695	.2466	.2291	.2038	.1490	.3802	.3482					
	2	.2800	.2734	.2345	.2601	.3140	.2833	.2702	.2473	.2296	.2044	.1490	.3810	.3490	.0000				
	3	.2848	.2781	.2381	.2646	.3191	.2882	.2747	.2517	.2330	.2087	.1490	.3885	.3542	.0003	.0002			
	4	.2808	.2741	.2351	.2608	.3148	.2841	.2709	.2480	.2301	.2051	.1490	.3819	.3498	.0000	.0000	.0001		
	5	.2673	.2610	.2251	.2487	.3002	.2702	.2581	.2360	.2208	.1939	.1477	.3660	.3346	.0019	.0022	.0040	.0024	

.0088 ± .0010

.2660 ± .0072

.0011 ± .0005

Table 5. Frequencies of the Oreochromis mossambicus allele at 6 diagnostic loci in samples of *O. niloticus* populations.

LOCUS	ALLELE	Philippines											Taiwan	Thailand
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Gpi-1	A	0.250	0.250	0.150	0.125	0.075	0.172	0.338	0.225	0.206	0.162	0.132	0.025	0.000
Mdh-1	A	0.100	0.125	0.175	0.275	0.100	0.121	0.112	0.250	0.206	0.294	0.500	0.050	0.000
Sdh	A	0.125	0.094	0.275	0.075	0.125	0.121	0.125	0.125	0.294	0.217	0.267	0.000	0.025
Sod	B	0.050	0.125	0.150	0.150	0.121	0.034	0.062	0.100	0.176	0.182	-----	0.000	0.050
Mp-2	B	0.062	0.225	0.175	0.175	0.000	0.034	0.088	0.150	0.088	0.294	0.289	0.000	0.000
Mp-3	B	0.125	0.094	0.125	0.100	0.075	0.207	0.075	0.150	0.206	0.294	0.316	0.000	0.207
Average ±SE		0.117 ±0.030	0.125 ±0.027	0.183 ±0.023	0.150 ±0.029	0.067 ±0.019	0.115 ±0.029	0.133 ±0.042	0.167 ±0.024	0.196 ± 0.027	0.240 ±0.025	0.301 ±0.054	0.012 ±0.009	0.012 ±0.009

A high correlation (r = -0.991) was observed when D between *O. niloticus* and *O. mossambicus* was plotted against the correponding frequency of *O. mosambicus* in the *O. niloticus* sample (Fig. 2). This relationship indicated that as the degree of introgression increased, the genetic degree distance from *O. mossambicus* decreased. The sample with the highest degree of introgression (0.031) had the least genetic (0.1487 ± .0003) from *O. mossambicus*. It also had the largest D value (0.0478) from Taiwan *O. niloticus*.

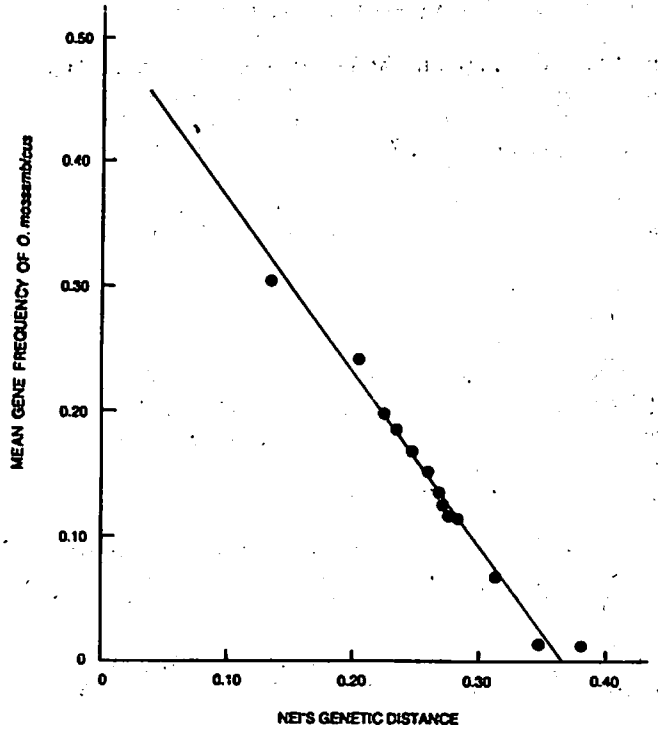

Figure 2. Plot of mean frequency of Oreochromis mossambicus genes from samples of 13 *O. niloticus* population and Nei's genetic distance (O) from *O. mossambicus*.

REMARKS

O. mossambicus introgression in almost all Philippine *O. niloticus* populations and its widespread occurrence in Philippine inland waters have implications for the future of the Philippine tilapia industry. Growth performance of existing or local populations of tilapia could be improved by selective breeding and hybridization. However, for stock improvement programs, it is not clear yet whether the present genetic resources are useful or whether the introduction of relatively pure breeds is needed.

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Selection Program for Nile Tilapia at the Freshwater Aquaculture Center

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ABSTRACT

This paper presents the design and preliminary results of a selection program undertaken at the Freshwater Aquaculture Center of the Central Luzon State University on Nile tilapia to develop one or more new strains with improved commercial value. Three basic approaches for the selection process were done: a) selection for broodstock from among individuals and the same age reared in common environment; b) selection process focused on families compared under equivalent environmental conditions and broodstock selected at random from families which have been judged to be superior; and c) combination of the two. The traits identified and the most important for selection are growth rate, age of reproduction, and fecundity.

INTRODUCTION

In order to obtain the best available seed stock for an aquaculture operation, one must choose among species and then among strains to find the best fish. However, if the performance of the fish still does not satisfy the producer, then the remaining option is to genetically improve the fish stock being cultured through a breeding program, selection, and/or genetic engineering. Selection is the traditional mechanism for improving the performance of domestic strains of animals and plants. It has the advantage of being applicable in simple or complex forms and of being manageable by people untrained in biology. The paper presents the design and preliminary results of a selection program undertaken at FAC for Nile tilapia.

The objective of the tilapia selection program at FAC is to develop one or more new strains of *Oreochromis niloticus* with improved commercial value. The traits identified as most important for initial selection are growth rate, age of reproduction and fecundity.

There are three basic approaches to the selection process. First, broodstock can be selected from among individuals of the same age reared in a common environment. This is called mass selection. Second, the selection process can focus on families compared under equivalent environmental conditions and on broodstock selected at random from families which have been judged to be superior. Third, the two former approaches can be combined as what has been done in this program.

In the selection of multiple traits, an additional decision must be made on how to combine the selection process for all (Falconer, 1982). The traits can be selected in sequence: one character being under selection for a few generations followed by the other traits, each being selected separately for one or more generations. This is called tandem selection.

Independent culling, the next alternative, involves the selection of all traits in each generation. In here, individuals or families are culled first for one trait, then for each additional trait independently. Thus, there would be a series of separate selections with those individuals which survived all the cullings constituting the broodstock for the next generation.

The last method involves the creation of an index which incorporates all of the trait values of an individual or family with each trait given a weighting factor according to its economic value and degree of genetic determination. This form of multiple trait selection is

called index selection and is the most complex, but most efficient form.

At FAC, independent culling will be used until the need is demonstrated for index selection and until the data is available to calculate the weighting factors for the traits under selection.

MATERIALS AND METHODS

Broodstock

Four strains have been incorporated in the foundation stock of this program. These strains will be designated by the country from which they were originally imported into the Philippines, except the FAC strain which can be traced to Singapore but will be called Philippine strain. The others are the Singapore strain from BFAR at CLSU, the Israel strain from BFAR at CLSU, and the Taiwan strain (imported by ICLARM in 1984 to BFAR at CLSU). Crossing between stocks is encouraged by stocking females of each strain in pools with single males. Equal number of males from each strain are stocked in the pools. All broodstock fish are tagged.

The program was initially started without the FAC strain, but such strain was included in the second stocking of breeding pools in order to broaden the genetic base of the initial populations for selection. It is likely that none of the four is *Oreochromis niloticus;* however, in a selection program, the presence of genes from other species, i.e. *Oreochromis mossambicus* and *Oreochromis aureus*, is not necessarily detrimental because the selection process is used to modify the genetic variation in such a way that the value of the stock is increased.

Offsprings are collected from the breeding pools initially at weekly intervals and later, at intervals of 10-14 days. Females are seined individually and their mouths inspected for eggs or fry. All batches of eggs are counted and placed in some type of incubator which provides for the movement of the eggs. Yolk-sac fry are placed in small aquaria.

Rearing of Family Groups

All spawns that have more than 100 fry surviving up to free swimming stage, i.e. complete yolk-sac absorption, are stocked into hapas. Each family has only one hapa containing 100 fry. These are sampled at two-week intervals to obtain weight and survival rates. Individual weights are taken after four weeks of growth.

In the first series of hapas, feeding rate was based on body weight of the fish. Feeding schedule in the second series of hapas are based on a growth curve of five heaviest hapas in the first experiment. At eight weeks of age, the fingerlings are transferred from the fine-mesh hapas to $1m^3$ large-mesh cages.

In the first series of cages, feeding was at 10% of body weight of the fish in each cage. The feeding rate in the second series will be 10% of the growth curve described above. Fish are sexed at the first sampling when it is already practical to do so, usually after 12 weeks.

Selection of Growth

All families have been subjected to selection for high and/or low growth lines at the 14 week sampling period. The mean twelve-week weight of families is compared to determine which families contribute to the high line, low line or both. If two families are sampled on the same day, the one with the largest 12 week weight contributes fish to the high line while the other is used for the low line. If three families are sampled, the intermediate family contributed to both. Thus families of even numbers are divided evenly and an odd number results in one family that contributes to both. Families stocked on different dates are not compared because evidence indicates that temporal environment changes swamp the genetic differences among families.

Up to 20 males and 20 females are weighed for the selection. The two eight largest and/or smallest males and the largest and/or smallest females are chosen for the broodstock ponds. This will result in the preferred sex ratio of one male to four females (PCARRD, 1985). To date, 14 families have reached the selection stage. Data have been summarized for the first eleven.

Selection of Age of Maturation

After selection for growth in the cages is completed, weekly sampling is conducted to get more accurate data on reproduction. Each female is checked for eggs or fry in the mouth. Reproductive females are held separately in labeled containers and their eggs or fry are siphoned into a beaker for transport to the laboratory. Non-reproductive females are also taken to the laboratory in a group for weighing.

Females that reproduce in cage and are younger than eighteen weeks are selected for early-maturing line. Reproductive females older than eighteen weeks are selected for the mate-maturing line. Accumulation of late-maturing females has just begun such that the data that will be presented will only be on early reproducers.

RESULTS

Parental Reproduction

The first stocking of the breeding pools resulted in 69 spawns. The fecundity of the females ranged from 40-1,273 eggs, or 0.9-17.0 eggs/g female body weight. Average fecundity per female was 580 eggs. The survival of eggs to fry averaged 24% while the survival of yolk-sac fry to fry under laboratory conditions was 66%.

Two groups of Israel strains were used, one small (100g) and one large (250g). Neither group gave satisfactory results. The large group gave no spawns, perhaps because they were larger than the males.

In the second stocking, two females of the Israel strain were stocked in each pool to encourage reproduction. The Israel strain seem to mature later than the other strains which is a desirable charateristic. The stocking yielded 54 spawns in three seining. The average number in each type of family is 946 eggs, 392 yolk-sac fry, and 486 fry. The experiment is in progress.

Growth of Families

Thirty six families were stocked in hapas. Eight weeks after stocking, these families weighed from 1.7 to 4.0 g with a mean of 2.7 g and a standard deviation of 0.55 g. Preliminary measurements of males and females showed no significant differences in weight.

The effect of genotype on growth is often estimated by correlation of half-sib or full-sib groups. Half sib are families that share only one parent. This method requires that all families are grown under equivalent environment. When a half-sib correlation was done with the eight-week weights of 20 individuals per family, the results were not significantly different from zero.

Between full sibs in the same data set, the correlations were high ($r=0.55$). This disrepancy was due to the effects of different stocking dates and environmental differences among the hapas.

The effect of stocking dates was significant ($F=2.36$, $df=4$) as was the effect of families within dates ($F=8.65$, $df=10$). The latter effect is combined with the environmental influence of the different hapas in which the families are grown.

Sexual Maturity

At 14 weeks, the sex distribution ranged from 36% to 60% males. The female weight ranges from 64% to 89% of male weight.

Eight of the 10 cages had reproduction at 10 weeks, 6 of the 10 cages in 16 weeks, and 4 of the 5 cages at 17 weeks. In 16 cases, weights were taken for reproductive and non-reproductive tilapias in the same cage. Reproductive females were heavier in 6 cases, lighter in 9 cases, and equal in 1 case. Although not included in this data, reproduction in two females weighing less than 8 g was observed. The number of eggs of early maturing females ranged from 45 to 372 and the number of eggs per gram body weight averaged 11.

DISCUSSION

The objective of this program is to improve the performance and profitability of tilapia. At this point in time, it is not yet known whether that objective will be achieved. Much has been learned, particularly about the maturation of *T. niloticus*, but the performance of the offspring of the selected broodstock must be tested before the selection program can be claimed as successful.

The methodology used is labor intensive. Simpler methods of selection can be designed but amount of information obtained will be less. Until the genetics of tilapia is studied more intensively, it cannot be said that rearing individual families gives any advantage to a selection program. Two modifications should be made in the procedure to make it more accurate. Families should be stocked in replicate hapas and more families should be tested on each stocking rate. The design of an effective egg incubator for tilapia would also facilitate this type of study.

The growth of fish in this study has not been equal to that obtained in normal pond stockings. This can be attributed mostly to density effects. High density environments for selection could create a problem if there is an interaction between density and genotype.

Good growers at high density perform poorly at low densities. This needs further investigation.

The selection intensities used are too strong for a long term program because they encourage a rapid loss of genetic variation. It is important to determine the genetic contribution to growth before continuing with a selection program. If there is a moderate contribution of genotype to sizes at 14 weeks, then there should be a significant

differences in size between the offspring of the high and low lines.

Reproduction has occurred at smaller sizes than have ever been recorded before for *O. niloticus* (Peters, 1963; Smitherman *et al.*, 1983). Observations indicate that these small fish are also voracious predators of their own eggs and fry. This could account for the lack of observations on reproduction at this age and size. There is clearly a need to deter this early reproduction. The studies reported here are still in progress. More data as well as a test on the effect of selection on this trait are needed.

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Evaluation of Tilapia Strains and Hybrids for Land-Based Systems

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ABSTRACT

Evaluation studies were conducted on the growth performance, survival, and sex ratio of three generations of Oreochromis niloticus strains (Philippine (Pn) and Singapore (Sn) strains) in ponds. Growth rate of progenies from Pn × Sn was higher than the Sn × Sn. First generation progenies (F_1) from the two crosses gave the highest growth rate compared to the second (F_2) and third (F_3) generations. Survival rate was comparable between the two crosses. Among the generations, Sn × Sn cross gave a higher male percentage than Pn × Sn.

INTRODUCTION

The many attributes of tilapia as an aquaculture species have generated much interest among researchers, farmers, and the public consumers. The qualities of this fish such as its excellent flesh quality, resistance to parasites and disease, market acceptability, and the available technologies in its culture and propagation have contributed to the rapid development of the tilapia industry.

However, one problem that deters the expansion of the tilapia industry in the country is the inferior quality of stocks used in the different aquaculture production systems (PCARRD, 1985). It appears that interbreeding has occurred between the wild *Oreochromis mossambicus* and the cultured *O. niloticus* stocks which has contributed to the deterioration of cultured stocks.

To abate this problem, a long term genetics program for tilapia is needed to establish specific criteria for selection of high quality tilapia

breeders to be able to develop fast growing strains suited to specified environments and management practices which will be used to replace the existing contaminated strains.

This paper presents the results of recent studies conducted at the FAC on the evaluation of the different *O. niloticus* strains in pond conditions.

MATERIALS AND METHODS

A series of evaluation studies on the F_1 (Generation 1), F_2 (Generation 2), and F_3 (Generation 3) progenies of strains of *Oreochromis niloticus* (Sn x Sn and Pn x Pn) was conducted in three culture trials. The trials were conducted in six (6) 0.05 ha ponds at the FAC during the following intervals: F_1 progeny evaluation - January 25 to May 25, 1984; F_2 progeny evaluation - July 3 to November 5, 1984; and F_3 progeny evaluation - December 10, 1984 to April 13 1985.

Standard pond preparation was followed. Each pond was drained and applied with Gusathion A to remove unwanted fish species and other organisms. Experimental ponds were refilled with deep well water and fertilized with chicken manure and 6-20-0 at the rate of 2,000 kg/ha and 50kg/ha, respectively. Inorganic fertilization was done bi-weekly throughout the culture period.

Experimental ponds for F_1 progeny evaluation were stocked with fingerlings at 5,000 per ha and 6,000 per ha for F_2 and F_3 progeny evaluations. Biweekly sampling of the test progenies was done to monitor growth increment and for feed adjustment. The progenies were given a diet consisting of 60% rice bran, 25% fish meal, 15% copra meal, 10% booster feeds, and 1% vitamin premix. Feeding was done twice at 10% of the fish body weight during the first month of culture, 80% on the second month and 5% on the third and fourth months. Each culture trial lasted for 120 days.

RESULTS AND DISCUSSION

Growth and Survival of Tilapia Progenies

The average daily growth increment was highest in the first generation (F_1) with 1.436 g and 1.274 g from the crosses Pn x Sn and Sn x Sn, respectively. This was followed by the second generation progenies (F_2) with 1.28 g and 0.803 g, and the third generation progenies with

0.753 g and 0.689 g following the same order of crosses. It was also noted that growth rate of Pn x Sn was slightly higher than Sn x Sn in all generations. Similar results were also obtained in the work of Kuo and Abella (1981).

Although no direct comparisons can be made on the growth rates and survival of the three generations because of differences in time and stocking density (F_1 has 250/500 m^2), it appears that F_1 progenies showed better performance than F_2 and F_3 progenies. It is also apparent that there is a decrease in the growth performance of the subsequent generations. The fast growth rate in F_1 progenies may be an indication of a hybrid vigor which is manifested in plants and other domesticated animals. Several studies have reported the rapid growth in hybrids (Hickling, 1963; Suffern *et al.*, 1978; Guerrero *et al.*, 1980; Lovshin,1982).

The decrease in the growth rate in the F_1 and F_2 progenies may be attributed to the gradual disappearance of the "hybrid vigor effect" in the second and subsequent generations (Andriyasheva, 1970).

Survival was highest in the Pn x Sn F_2 progenies with 97.3% but statistical analysis revealed no significant difference in the survival rate.

Percentage Sex Distribution

Progenies in all generations in Sn x Sn have higher male percentage than the Pn x Sn. Analysis of variance showed that there was a significant difference ($P<0.01$) in the percentage sex distribution between the progenies of the two crosses. This finding however did not conform with the works of Chervinski (1967) and Majumbar and Mc Andrew (1983) where a 1:1 sex ratio was obtained. This shows the complexity of sex determination in tilapias where biasness towards one sex is observed.

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Special Stock Manipulation Techniques for Increasing Production of Large Size Tilapia in the Philippines

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ABSTRACT

The paper reviews the special stock manipulation techniques commercially applied for the production of large size tilapia in the Philippines. These techniques include mass selection of breeders, hybridization, and sex reversal. Of these techniques, mass selection is the most extensively applied. The sex reversal technique was found to be more effective and efficient for commercial application compared to hybridization. For commercial tilapia farming in the Philippines, a combination of mass selection of breeders and sex reversal of fry for production of high quality fish is recommended.

INTRODUCTION

Of the four tilapia species introduced in the Philippines, the Nile tilapia (*Tilapia nilotica*) is the most extensively cultured. The Mozambique tilapia (*T. mossambica*) is mainly limited to brackishwater ponds. The Blue tilapia (*T. aurea*) has been used in hybridization studies but is not extensively grown. Zill's tilapia (*T. zilli*), a species not preferred for culture, occurs in the lakes and river systems of Luzon. The so-called red or colored tilapias (e.g. Gintong Biyaya) has also come about.

The worldwide problem of stunted growth in the tilapias attributed to over population in ponds has received much attention in the Philippines. Various population control techniques, including manual sexing, sex reversal, hybridization, and use of fish predators have been

applied (Guerrero 1974; Guerrero and Guerrero, 1975; Guerrero, 1979; Fortes, 1980; Lovshin, 1982).

With the intensification of tilapia culture and growing demand for large-size fish (150 to 250 g), there is a need to evaluate the various techniques available for stock manipulation of tilapia in the country for increasing production.

The purpose of this paper is to review the special stock manipulation techiques commercially applied for the production of large-size tilapia in the Philippines.

Special Stock Manipulation Techniques for Tilapias

Mass Selection of Breeders

Mass selection of breeders is the most widely applied stock manipulation technique for propagation of high quality tilapia in the Philippines. The technique involves the identification of tilapia species largely through phenotype characteristics (i.e. body coloration, fin appearance, gill raker counts, etc.) and selection of broodstock through a set of generally accepted standards (e.g. body conformation, no physical deformities, well-developed urogenital papillae, etc.).

There are, of course, limitations to the technique. For instance, it is difficult, if not impossible, to physically differentiate an "Israeli strain" of Nile tilapia from the "Philippine strain". In most cases, a tilapia breeder relies on the face value of stock at hand.

With electrophoresis, it is now possible to distinguish "strains" and hybrids through genetic markers. Although this facility is presently available in the country, it has yet to be fully appreciated by the industry.

The major concerns of tilapia hatchery operators in the Philippines are inbreeding and the contamination of their Nile tilapia broodstock with Mozambique tilapia. While species introgression is a broodstock management problem, I strongly feel that inbreeding of Nile tilapia stocks in the country similar to Mozambique tilapia has indeed taken place. This can be subject for discussion in the workshop.

Tilapia Hybridization

The crossbreeding of tilapia species for hybrid production with high male percentage (85 to 100%) is commerically applied in Israel using *T. nilotica* × *T. aurea*. The technique has also been successfully demonstrated with *T. nilotica* × *T. hornorum* in Brazil but has not been commercially applied because of the difficulty in producing adequate numbers of fingerling (Lovshin, 1982).

In the Philippines, a private corporation (Crust-Asian Resources Inc.) imported purelines of *T. nilotica* and *T. aurea* from Israel for the production of all male- hybrid. While a high percentage of male in the hybrids (85%) was initially reported, the group was not able to sustain production of such hybrid due to management problems. The corporation, unfortunately, shut down its field operations in 1984.

In an experimental study on three tilapia hybrids (*T. nilotica* × *T. aurea*, *T. nilotica* × *T. mossambica* and *T. mossambica* × *T. aurea*) conducted at the Freshwater Aquaculture Center, Guerrero *et al.* (1980) found the best growth, survival, and the highest male percentage in the *T. mossambica* × *T. aurea* hybrid using freshwater ponds.

No significant differences in the growth of female *T. nilotica* × *T. aurea* hybrid over that of the Nile tilapia was detected by Guerrero (1983) in a cage culture study conducted in Laguna de Bay.

Production of *T. nilotica* fry in concrete tanks was more efficient than that of female *T. nilotica* × male *T. aurea* because of incompatibility and interspecific differences.

Tilapia Sex Reversal

The control of sex direction in sexually undifferentiated fry through hormonal treatment has been achieved in several tilapia species (Guerrero, 1979). Commercial application of the sex reversal technique is now a reality.

Using shaded concrete tanks, Rothbard *et al.* (1983) reported success in the commercial production of sex-reversed tilapia fry with 98 to 100% males using 60 ppm ethyltestosterone/g diet for 28 days. Buddle (1984) indicated the feasibility of treating tilapia fry for sex reversal in outdoor cages.

In the Philippines, the Meralco Foundation, Inc. Tilapia Culture and Research Project in Jala-Jala, Rizal has produced 99% male *T. nilotica* with sex reversal treatment of fry using 30 ppm methyltestosterone/g diet for 21 days in outdoor concrete tanks. A private company in Bay, Laguna (Aquatic Biosystems) has prepared a commerical diet known as SRT-95 for sex reversal treatment of tilapia fry in low-cost outdoors system (Rodriguez, 1985).

A constraint in the commercial application of the reversal technique in the country which is that of producing massive numbers of fry of the right size (9 to 11 mm) and age (ca 10 days) for treatment, has been overcome. Breeding techniques for tilapia using net enclosures, earthen ponds, and concrete tanks have improved markedly in recent years.

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Evaluation of Tilapia Cage Culture Project in Mindanao

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Davao City

ABSTRACT

The economic viability of tilapia cage culture in the Mindanao region managed by the Southern Philippines Development Authority from 1979-1985 is discussed. Tilapia cage culture in Lake Pinamalay was not successful due to lack of technical knowledge and poor acceptability of tilapia in the area. On the other hand, tilapia cage culture in Lake Buluan proved to be economically viable with the good market price of tilapia in the area. It is hoped that the poor acceptability of tilapia in certain areas of the region would be temporary.

INTRODUCTION

In evaluating the tilapia cage culture in Mindanao, certain conditions which I feel are peculiar to the area should be considered. First, Mindanao is still abundant in its fishery resources. When the Southern Philippines Development Authority (SPDA) started fish cage culture at Lake Buluan, it could hardly find local fishermen willing to be beneficiaries or caretakers. Indeed, why should anyone bother to raise fish in cages for 4-5 months when he can catch the same volume in 4-5 days. Second, perhaps like their brothers from the North, the local residents still prefer marine fishes. In fact, tilapia is still unknown to a lot of people living along the coastal areas. Third, fish cage culture is a relatively new industry for which a certain level of technical know-how is necessary, I believe that we lack this requirement. Lastly, to be accepted, the activity must prove to be economically viable.

At this point, let me discuss with you the SPDA's experiences in tilapia cage culture. Perhaps from these experiences, we can evaluate

the industry in Mindanao. There are four (4) lakes in Mindanao where SPDA is undertaking cage/pen culture of tilapia.

A brief understanding of SPDA's mandate and activities will provide you with an insight on the prospect of the aquaculture industry, specifically of tilapia cage/pen culture in Mindanao.

The SPDA

The Southern Philippines Development Authority (SPDA) is a government owned and controlled corporation created in April 22, 1975 thru PD 690 as amended by PD 1703. It is tasked with the responsibility of accelerating and promoting the balanced growth of Southern Philipines within the context of national plans and policies. To carry out its mandate, the SPDA has been specifically authorized to undertake developmental and economically viable ventures within Regions IX, X, XI and XII. The developmental and economically viable ventures may be in the fields of agriculture, power, infrastructure, education, energy, public utilities, housing, land development, manufacturing, exploration and utilization of natural resources, and other fields.

As of March 31, 1985, SPDA has established a total of 44 varied projects, subsidiaries and equity investments. The total investment exposure is ₱236.742 Million (Table 1).

Table 1. SPDA investment exposures by industry (As of 31 March 1985).

Industry	Investment (₱M)	% of total
Aquaculture	109.261	46
Livelihood/Rehabilitation	40.879	17
Agro-Industrial Resettlement	25.320	11
Manufacturing	26.510	11
Housing/Industrial Estate	12.440	5
Poultry/Livestock	9.030	4
Agro-Industrial	6.360	3
Equipment Services/Marketing	3.890	2
Hotel Industry	2.782	1
Total	236.472	100

As reflected in the above table, the bulk of the authority's investment is in aquaculture. This will remain so in the immediate future.

The authority's investment in aquaculture is shown in Table 2. Out of the total aquaculture investment of SPDA, ₱48.021 M or 44% is in fish cage/pen culture activities. One of the primary species being cultured is tilapia.

Table 2. SPDA aquaculture investment (As of March 31, 1985).

Project Code	Location	Investment (₱M)	Major Activity
BLFE-I	Vitali, Zamboanga City	39.240	Fishpond
BLFE-II	Duras, Zamboanga City	.100	Fishpond
BPMFP	Basilan	9.60	Fishpond
IMFDP	Bongao, Tawi-tawi	4.140	Marine fishing
BLRPHP	Naawan, Misamis Oriental	7.113	Prawn hatchery
PPDC	Panaon, Misamis Occidental	0.250	Prawn hatchery
LMIDP	Lake Mainit,Agusan del Norte	0.100	Fish cage
MFP	Lipon,Davao Oriental	0.793	Fishpond
LLC	Latayan, Sultan Kudarat	2.321	Fish cage
LBDP	Bulusan, Maguindanao	23.690	Fish cage/pen
LMDP	Pikit, North Cotabato	13.080	Fish cage/pen
LLFCCP	Marawi, Lanao del Sur	8.830	Fish cage
		109.261	

SPDA's Initial Exposure in Aquaculture

SPDA established its first tilapia fish cage culture project at the 30-hectare Lake Pinamaloy, Bukidnon in 1979. The project's facilities included twenty-four (24) units of 500m^2 rectangular grow-out cages, six (6) units of 200 m^2 breeding cages. These facilities, including a perimeter fence, cost ₱65,080.

Income estimate is based on a stocking density of 15,000 pieces of *T. nilotica* fingerlings per cage and a survival rate of 70%. The stocks were given rice bran as supplemental feed. The actual result however was below expectation. In our ten months of operation, we lost about ₱60,000 (Table 3). We had to suspend the operation and concentrate instead on our agricultural components.

Table 3. Bukidnon fish cage culture project actual operation result.

	Per Plan	Actual
Number of cages	24	24
Dimension (sq.meter)	500	500
Stocking (per cage)	15,000	15,000
Survival rate (%)	70	61
Culture period (month)	6	8
Number of fish per kg	6	14
Volume of fish harvested (kg/cage)	1,750	653.57
Selling price/kg (₱)	7	4.00
Total sales (₱)	12,250	2,614.28
Cost		
Fingerlings (80% average survival at ₱0.07)	1,312.5	1.470.59
Rice bran (at 2 kg/kg fish at ₱0.70)	2,450.00	2,767.10
Labor cost (average cost per laborer)	620.00	826.67
Overhead	375	
Gross income per cage	7,492.50	(2.450.08)

We admit that we failed to critically evaluate the economic result of our project. We could only surmise that the probable causes for the failure were the low quality breed of the tilapia we raised, the low lake productivity, the poor market for tilapia, and our inadequate managerial exposure to such kind of undertaking. I have endeavored to present this experience to emphasize one important point I raised earlier, that technical know-how is crucial for a project to be commercially viable. An ordinary entrepreneur would definitely think a thousand times before he tries this activity again after losing ₱60,000.

Status of SPDA's Fish Cage Culture Projects

Allow me to deal with the operations of the lake Buluan Development Project (LBDP), the biggest tilapia fish cage/pen culture project of SPDA or perhaps the entire Mindanao. It is at this area where we achieved a certain degree of success. I wish to inform you however, that as of February 1985, we have temporarily suspended the operation of the project at the lake due to the deteriorating peace and order situation.

As of December 1984, the Lake Buluan Development Project has completed several production facilities (Table 4).

Table 4. List of LBDP completed facilities (As of December 1984).

Facilities	Capacity/No.
Ice plant	10 tons
Fish cages/pens	
Fish cages	1,000 units, 5 m × 10 m × 4m
Nursery cages	980 units, 3 m × 3 m × 3m
Fish pen	
One (1) unit demonstration pen	4 hectares, circular
One (1) unit corporate pen	48 hectares
Seven (7) modules fish pen	24 hectares per pen
Hatchery complex	2 hectares fishpond with about 800 units cages

The Cages

The cages (5m×10m×4m) are made of knotless polyethylene nets resembling an inverted mosquito net. The nets are tied to bamboo framing with poles spaced about two (2) meters apart. Each unit was estimated to cost about ₱1,217. Each cage was stocked with 2,000 pieces of *T. nilotica* fingerlings raised for an average of 5 months without supplemental feeding. Based on our actual experience, survival rate is between 60-75% with ten fish weighing an average of 165-200 g each. The estimated income from cage operations in Lake Buluan is shown in table 5.

Table 5. LBDP result of fish cage operation.

Stocking density/cage	2,000
Survival rate	60%
Weight at harvest	165-200 g
Estimated harvest (kg)	218.18
Selling price/kg	10.00
Total sales	2,181.82
Less Cost	
Fingerlings (at ₱0.12 per piece + 10% allowance)	266.67
Depreciation of cages (2 years life span)	304.25
Repair and maintenance (5% of cost)	60.85
Miscellaneous	150.000
Sub Total	781.77
Gross income	₱ 1,400.05

The LBDP hatchery is capable of producing about 500,000 fry per month. With the steady supply of tilapia fry, tilapia cage culture is seen to be viable at least in Lake Buluan. Thus, in the early part of 1984, we started distributing about 400 cages to 100 fishermen/beneficiaries who were convinced that the fish cage culture of tilapia is a viable undertaking. Under this concept, each beneficiary shall be awarded four (4) units of cages and one (1) unit of nursery cage. The total cost including that of fry to be supplied by SPDA will be amortized within two years by the beneficiary out of the proceeds or the sales of his harvest. SPDA will market the harvest of the beneficiary and will automatically deduct the semestral installment and the cost of fry. This is the new management concept we wish to introduce not only for our cages and pens but for our fishponds.

Market Trends

During the early part of 1980, when we started the initial planning of Lake Buluan Development Project, the prevailing market price of *Tilapia mossambica* in Davao City was only ₱4-5/kg. *T. nilotica* culture in cages at Lake Sebu were sold at ₱6-7/kg. In 1983, when we harvested the fish from cages in Lake Buluan, we were selling *T. nilotica*, weighing 200-250 g each at ₱11/kg in Buluan and ₱15 per kilo in Davao City. The latest price for the same size in Davao City was ₱18/kg. About one (1) ton is being sold daily at the Davao market. During the peak of our harvest, we were disposing an average of 2 tons

daily just for the neighboring municipalities of Buluan. We were even starting to receive advance orders. In our SPDA main office in Davao City alone, we were supplying an additional order of 200-300kg weekly for our employees.

T. nilotica has definitely gained market acceptance considering the fact that at peak fishing season, galunggong would sell only from ₱12-15/kg. This shows that the poor acceptability of this species in certain areas is only temporary. In due time, I believe tilapia will fare even better than milkfish in the market.

CONCLUSION

In closing, I wish to reiterate that tilapia fish cage culture in Mindanao is a viable economic venture. But while the industry is economically viable, a certain level of technical knowledge is still required.

Let us look at the case of Mindanao. We have been repeatedly harping on this. We need our technology in order to fully develop the potential of the area. We, from Mindanao, sometimes could not help but feel totally ignored by our brothers from the North who are admittedly, more technically equipped. Let us all together channel our efforts towards the economic development of Southern Philippines. We at SPDA firmly believe that Southern Philippines would ultimately be the major food base where the entire country would depend.

Workshop Output

IDENTIFIED RESEARCH AREAS

I. Broodstock Management and Selection

1. Broodstock quality*
2. Procedures
3. Manpower
4. Facilities

II. Selection for genetic improvement

1. Development of strains by user group
2. Multiple traits** by priority
3. Hybridization

III. Extension

Sex reversal; other tested procedures/technology generated

*Broodstock quality- the following should be determined:

a. Stock size
b. Longevity
c. Replacement/selection
d. Source of stock

**Desired characters of species to be cultured:

1. Fast growth
2. Tolerance to environmental conditions
3. Survival
4. Consumer preference
   a. color
   b. conformation
   c. flesh characteristics
   d. % dressed weight
   e. taste
5. Late maturity
6. Easy harvesting
7. Disease resistance

INSTITUTIONAL LINKAGES AND RESPONSIBILITIES

AGENCY	RESPONSIBILITY
BFAR	-Genetic resources
FFH-ETC	-Maintenance and dispersal -Training and extension -Monitoring of new stocks (importation of new stocks)
SEAFDEC, Binangonan	-Cage and pen culture (I & II identified problem areas) for lake fisheries and training along this line
FAC (lead agency)	-Rice-fish, pond culture (I & II) and cage (dams, reservoirs) -Training
BAC	-Brackishwater ponds and cages (I & II identified problem areas) in estuaries -Training
MSI	-Biochemical genetics and stock identification
LLDA	-Hatchery operations and pond procedures (Laguna and Rizal) -Extension
Meralco Foundation	-Hatchery, sex reversal, intensive cage culture -Research and extension
UPLB	Data storage and analysis for quantitative genetics; Bio-chemical genetics
SPDA	-Verification and training collaboration
BAEcon	-Economics
ICLARM	-Information services

Appendices

Seminar-Workshop Programme

20 June 1985 (Thursday afternoon)

Arrival and registration of participants
Tour of FAC and FFH-ETC
Dinner
Socials

21 June 1985 (Friday)

MORNING SESSION

8:00	OPENING CEREMONIES	
	National Anthem	
	Welcome Address	**Dr. Rodolfo Arce** Director CLSU-FAC
	Workshop Rationale	**Dr. James Lester** CLSU-FAC
	ORGANIZATIONAL PAPERS	
	Experiences on the culture of tilapia under saline conditions	**Dr. Romeo D. Fortes** UPV-BAC
	Tilapia genetics research at FAC- An Overview	**Mr. Renato Recometa** CLSU-FAC
10:00	COFFEE BREAK	
	Broodstock management procedures at FFH-ETC for protection of pure strains and hybrid fingerlings	**Mr. Melchor Tayamen** FFH-ETC
	Evaluation of tilapia cage culture in project in Mindanao	**Engr. Esa Bayani** SPDA

OPEN FORUM

Moderator	**Mr. Ruben Sevilleja** CLSU-FAC

AFTERNOON SESSION

1:00 GENETIC RESOURCES AND EVALUATION

Tilapia genetic resources in Asia	**Dr. Roger Pullin** ICLARM
Levels of genetic variation in tilapia stock-Implications for aquaculture	**Ms. Zubaida Basiao** SEAFDEC-BRS
Genetic characterization of cultured Philippine tilapia stocks	**Ms. Josephine Pante** UP-MSI
Evaluation of tilapia strains and hybrids for land-based systems	**Mr. Tereso Abella** CLSU-FAC

OPEN FORUM

3:00 COFFEE BREAK

STRAIN IMPROVEMENT

Selection program for Nile tilapia at FAC	**Dr. James Lester** CLSU-FAC

ECONOMIC CONSIDERATIONS

Effect of stock quality on profitability of tilapia production	**Mr. Romulo Petines** Fish Farmer
Economic importance of improved strains of tilapia	**Ms. Emma Escover** ICLARM
Special stock manipulation techniques for increasing production of large size tilapia in the Philippines	**Dr. Rafael D. Guerrero III** Aquatic Biosystems Bay, Laguna

OPEN FORUM

Moderator — Ms. Arsenia Cagauan, CLSU-FAC

22 June 1985 (Saturday)

MORNING SESSION

8:00 OPENING REMARKS
WORKSHOP
COFFEE BREAK
WORKSHOP
PLENARY SESSION

LIST OF PARTICIPANTS

1. Tereso **Abella**
   Research **Biologist**
   Freshwater **Aquaculture** Center
   Central **Luzon** State University (CLSU-FAC)
   Muñoz, **Nueva** Ecija

2. Rodolfo **Arce**
   Director
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3. Miriam **Balgos**
   Science **Research** Specialist II
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4. Zubaida **Basiao**
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5. Esa **Bayani**
   Chief, **Project** Development Division
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6. Ernesto **Belvis**
   Southern **Philippines** Development Authority (SPDA)
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7. Lita **Benitez**
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9. **Valeriano Corre, Jr.**
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10. **Ivan Duka**
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16. **Ruben Medina**
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17. **Diosdado Oro**
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18. **Cesar Pagdilao**
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19. **Ma. Josefa Pante**
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Diliman, Quezon City

20. **Romulo Petines**
Private Sector

21. **Roger Pullin**
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22. **Renato D. Recometa**
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23. **Ruben Reyes**
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24. **Ma. Severa Samaniego**
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PARTICIPATING AGENCIES/ORGANIZATIONS

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Tilapia Hatchery- Extension Training Center

Central Luzon State University

Freshwater Aquaculture Center

International Center for Living Aquatic Resources Management

Laguna Lake Development Authority

Southern Philippines Development Authority

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