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Genetic Diversity in Aquaculture

A programme for economically and socially sustainable conservation and development

Final narrative report (July 1993 - July 1996)

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Programme objective

The objective has been to develop an interdisciplinary policy-level and community-level programme for preserving the genetic biodiversity of aquaculture breeds, while alleviating rural poverty through the improvement of local and traditional broodstocks.

The development and worldwide dissemination of new aquaculture breeds is likely to be accompanied by a rapid decline in the genetic diversity of wild and domesticated stocks. We can predict this decline both by analyzing the technical nature of many of the current breed improvement programmes and also by historical analogy. The ongoing "Green Revolution" in agriculture has greatly diminished the genetic biodiversity of domesticated land plants and animals. A comparable genetic revolution in aquaculture is about to begin.

It is essential to foresee, and if possible forestall, a major loss of aquatic genetic resources. It will not, however, be easy to integrate genetic conservation with the equally important goal of genetic progress. Breed improvement programmes threaten the genetic integrity of native populations by genetic contamination, and threaten the very survival of domesticated breeds by competitive economic replacement ("genetic erosion"). In Western countries including Canada, Norway, the UK and the USA, the conflict between aquaculture and genetic conservation is a political issue that has the potential to block completely the further expansion of salmonid aquaculture. It will soon become an issue in Africa (especially with tilapia) and Asia (especially with carp).

The objective of genetic conservation *must* be made consistent with the objective of genetic improvement. The Green Revolution in agriculture has been a magnificent achievement. The time has now come when new strains of fish and shellfish are also needed, and needed urgently, to meet the demand for increased food production in developing countries. The conflict between this objective and the need to conserve existing biodiversity is a problem that is global in geographical extent and multi-agency in its implications for development assistance.

Summary of project components

It is now well recognized that genetic improvement and genetic conservation should both be given high priority in any forward-looking agenda for development. The focus was on aquaculture genetics, where IDRC had a strong comparative advantage at the beginning of the programme through its long-standing support of the Aquaculture Genetics Network in Asia.

The overall programme was intended to develop procedures that will help national governments to balance their development and conservation objectives in aquaculture genetics. There are several aspects to be considered: obtaining the necessary technical information, analyzing the issues, formulating the appropriate policies, implementation.

(1) Identification of the aquaculture breed improvement needs and priorities of farmers, especially artisanal and small-hold farmers, in developing countries. This "problem definition" research component focuses the project on a limited number of aquaculture sectors defined by their agroecologies and/or socio-economic characteristics. This aspect of the research was carried out mainly in Thailand and Malawi.

(2) Development of enabling technology for the genetic monitoring of native populations, breeds and gene banks in developing countries. Development of this new technology is important to the project because fish, unlike plants and terrestrial animals, are not amenable to pedigree registration using conventional techniques. The laboratory work was done in Canada and the field work in Africa and Asia

(3) Objective estimation of the risks to genetic biodiversity that are posed by various types and scales of breed improvement programme. This aspect was studied in all four participating countries (Malawi, Thailand Indonesia, China).

(4) Technical and policy recommendations for international aquaculture genetic development. These recommendations will be based both on technical (genetic) and socioeconomic analyses of costs and benefits of different mixtures of bio-conservation objectives, breed improvement strategies, and procedures for establishing effective genetic monitoring, access and ownership.

This final, evaluative stage of the project will be completed in 1997 - 1998 in collaboration with the FAO through its visiting fellow programme (R. W. Doyle).

Funding

Phase I of the project was funded for a two-year period, 1993-1995, by the International Development Research Centre (Canada). The project was extended for a third year with additional funding for an editorial workshop which was held in August 1996 at Wuxi, China. The project in Malawi received additional funding through the African Dissertation Internship Program of the Rockefeller Foundation.

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Summary of Project Activities

International coordination

1993	Nov 20-26	*Thailand.* Basiao, Doyle, Leith.
	Nov 29 - Dec 3	*Thailand.* Leith.
1994	Feb 12 - 19	*Thailand.* Basiao, Charles
	May 11 - 15	*Philippines.* Basiao, Doyle
	May 15 - 19	*China.* Basiao, Doyle
	May 19 - 22	*Thailand.* Doyle
	May 22 - 27	*Indonesia.* Basiao, Leith
	Jun 04 - 14	*China.* Charles
	Jun 19 - 25	*Indonesia.* Charles
	Oct 21 - 22	*China.* Charles
	Oct 23 - 28	*Indonesia.* Charles
	Nov 05 - 11	*Philippines.* Doyle
	Nov 11 - 17	*Indonesia.* Basiao, Doyle
	Nov 17 - 24	*Thailand.* Basiao, Doyle
	Nov 26 - Dec 3	*China.* Basiao, Doyle
1995	May 4 - 15	*Malawi.* Basiao, Doyle
	Aug 10 - 16	*Indonesia.* Basiao, Charles, Leith
	Aug 17 - 26	*Thailand.* Basiao, Charles, Leith
	Oct 20 - 25	*China.* Basiao, Doyle
1996	Aug 18 - 23	*China.* Basiao, Charles, Doyle, Leith

Workshops and short-term training

(1) Project planning, Bangkok, Thailand, 20-26 November 1993

(2) RRA training, Sukabumi, Indonesia; 22-27 May, 1994.

(3) Socioeconomic data analysis, Bogor, Indonesia , 10-16 August, 1995

(4) Editorial Workshop, Wuxi, China, 18 - 23 August, 1996

Long-term training

(1) Ms Shi Yonghong [Freshwater Fisheries Research Center, Wuxi] May - October, 1994. Training in biotechnology and development of microsatellite DNA probes for use in all projects. Marine Gene Probe Laboratory,

(2) Ambali, A.J.D. [Chancellor College, Malawi] 1996. The relationship between domestication and genetic diversity of *Oreochromis* species in Malawi: *Oreochromis shiranus shiranus* (Boulenger) and *Oreochromis shiranis chilwae* (Trewavas). Ph.D. Thesis, Dalhousie University, 204 pp.

(3) Kamonrat, W. [National Aquaculture Genetics Research Institute, Thailand] 1996. Spatial genetic structure of Thai Silver Barb (*Puntius gonionotus* Bleeker) populations in Thailand. Ph.D. Thesis, Dalhousie University, 150 pp.

Highlights of the programme

Effective interdisciplinary teams (Economics, Genetics, Sociology, Extension) were established in Canada and the participating developing countries.

Multi-person, interdisciplinary research teams were fielded in all projects. These represent the first teams to effectively coordinate the application of modern aquaculture biotechnology with its social and economic context in a programme for rural development. Interdisciplinary training workshops in farming systems and social sciences methodologies were held in Thailand and Indonesia, respectively in 1993 and 1994.

Each team involved cooperation among two or more national institutions. The programme is linked to other regional projects through the Indonesian national network of aquaculture genetics and the participation of some of the institutions in the International Network for Genetics in Aquaculture and the Asian Fisheries Social Science Research Network.

Appropriate "transferable" DNA fingerprint technology was been successfully developed at the Dalhousie Marine Gene Probe Laboratory (MGPL) as part of the training of project personnel from Thailand, Malawi and China.

Programme personnel (two Dalhousie PhD students, Drs. Ambali and Kamonrat, plus trainee Ms Shi) developed over a period of just a few months the DNA fingerprint probes needed for analyzing local farm strains of tilapia, common carp and *Puntius*.

DNA-level analyses confirm the social and economic perception that the farm populations studied in China, Indonesia and Malawi represent a valuable reservoir of genetic biodiversity.

This technology will help us to gauge the future success of policies undertaken to sustain the diversity and improve the quality of aquaculture strains.

Summary of results (by country)

MALAWI

Background

The diverse cichlid fishes of south-central Africa represent a unique genetic resource for the future expansion of aquaculture on that continent and globally. The government of Malawi, wishing to conserve its rich legacy of biodiversity, has banned the importation of exotic fish species.

The endemic tilapia *Oreochromis shiranus* has been brought under cultivation within living memory (40 years) in Malawi and offers an opportunity to study the genetic consequences of domestication of an endemic genetic resource in a developing country. The domestication of *O. shiranus* sp. for aquaculture in Malawi has its roots in the establishment of the National Aquaculture Centre (NAC) in 1959. Aquaculture extension in southern Malawi began in 1970 in the upland areas of Zomba district with the distribution of *O. mossambicus* to local farmers.

Aggrey Ambali's thesis

Five polymorphic microsatellite loci were analysed in samples of 14 wild and farm populations of *O. shiranus* sp. and one population of *O. mossambicus*. A natural zoogeographic structuring of *O. shiranus* can still be recognised in samples from wild, reservoir and farm populations analysed in 1993-1994 for polymorphism at microsatellite DNA loci. An unstructured questionnaire was administered to fish farmers and government stations in 1993 and 1994 to obtain socio-economic information, to find out when they started fish farming and where their fingerlings originated.

Farms growing different geographic subspecies of *O. shiranus* are closely intermingled in the southern region,. *The naturally-evolved relationship between genetic distance and geographical distance is no longer evident, however. There is instead a strong correlation between genetic distance and a matrix of recorded or remembered stock transfers among farms, fisheries stations and reservoirs.* Recent questionnaires reveal that these transfers are determined by cultural and socio-economic relationships among farmers.

The conservation outlook is not good: *effective number of neutral microsatellite alleles in farm stocks is declining at an estimated mean rate of 1.4% per year and an estimated 31% of alleles have disappeared from the captive (farm plus reservoir) gene pool.* Some nominal *O. shiranus* stocks are introgressed by *O. mossambicus.* Despite its enlightened import ban Malawi appears not to be in control of this irreplaceable genetic resource.

Farms growing fish from each of the three genetic groups are closely intermingled in the Zomba district. Questionnaires revealed that *transfer of broodstock and fingerlings between small scale farms was largely determined by the socio-economic relationships among farmers, not by any* *national Malawian aquacultural development or conservation agenda,* and not by geographic proximity *per se* within the local district. Some farmers from the same tribe reciprocated labour, while others were served by the same fish farming development project, Social status of the farm also played an important role; for instance the MKB population was sought as a superior breed by other farmers because MKB was considered to be a progressive farm.

Policy implications

The Malawian situation is typical of developing countries where little thought is given to genetics during aquacultural development, despite a strong awareness of other aspects of biodiversity conservation. The result has been impoverishment, mixing and contamination of a unique genetic resource at the subspecies and species levels. The combined genetic-social-economic study points to a novel strategy for conserving and making use of the aquatic genetic resources of Malawi.

> It appears that farmers who share common social characteristics tend to exchange genetic materials primarily among themselves. *Conservation of the genetic diversity of an endemic resource may be more sustainable over the long term if it is organised within social and community boundaries, rather than the geographic features within which it originally evolved.* The same consideration would apply to national breeding programmes aimed at improving yield while maintaining a multiplicity of breeds as a desirable hedge against environmental and socio-economic uncertainty.

THAILAND

Wongpathom Kamonrat's thesis

background

The population structure of the silver barb, *Puntius gonionotus* (Bleeker), was studied by examining genetic variation at four microsatellite loci. Natural populations from three major rivers in Thailand and nine hatchery stocks from the central region of Thailand were studied.

The natural populations maintained high genetic variability with an average 9 to 12.5 alleles per locus, 3.83 to 7.03 effective number of alleles, and average heterozygosity of 0.772 to 0.844. A low but significant genetic differentiation was observed among natural populations (q = 0.0053). A nonmetric multidimensional scaling revealed genetic discreteness between different watersheds in Thailand. Higher genetic divergence was observed between watersheds (average genetic distance of 0.265) that that of within watersheds in the central region (average genetic distance of 0.106 and 0.113 in the Chao Phaya and MaeKlong rivers, respectively).

The nine hatchery populations generally possessed levels of genetic diversity similar to natural populations. However, cluster analysis and genotype frequency analysis indicated that hatchery stocks were genetically differentiated from their natural counterparts. Average genetic distances between hatchery stocks and their natural counterparts ranged from 0.117 to 0.128.

The Thai Department of Fisheries has been engaging in a restocking program to enhance natural fish production for decades. Several millions fingerlings of many fish species, including *P. gonionotus*, produced by provincial fisheries stations are released into natural water bodies every year. Mixed stock analysis indicated that over 70% of the natural samples were of hatchery origins. This finding together with the evidence of genetic differentiation between hatchery fish and their natural counterparts indicated that restocking program poses a threat to genetic integrity of natural populations. In order to preserve the natural existing genetic resources, the results of this study would suggest that (1) management of the natural population of this species should be devoted to different watersheds rather than individual populations, (2) specific stocks for restocking should be established from a collection of natural populations within a watershed, and (3) stock transfer must not be practiced among stations outside a watershed.

The findings that (1) there are genetically distinct groups of natural *P. gonionotus* populations existing both within and between river systems in Thailand and (2) significant genetic contamination of natural catch samples by hatchery fish pose some implications for the management of this species in Thailand.

Based on the observations of this study, all hatchery populations exhibited high genetic variability comparable to those of natural populations. If released fish are produced from a large number of parents (e.g., 50 pairs or more) in each batch and if they are evenly released from several batches, they should pose little danger to natural populations in term of reducing their genetic variability.

Policy implications

Managers should also realize that the number of released fish contributing to the catch is more important than the number of fish being released. Quality of released fish should be emphasized to ensure their survival in the wild. This should include the use of natural food and release of larger fish.

Preserving the genetic integrity of populations is perhaps of much more important concern. As suggested above, the management of *P. gonionotus* populations in Thailand should give priority to different watersheds. The present DOF organization, in which different groups of stations are responsible for restocking the different river systems, is quite effective in maintaining stock integrity at the level of the watershed.

However, the genetic make-up of hatchery populations is questionable for fulfilling this role. Among all stations studied, only one station broodstock (*SBSTA*) was genetically similar to those of natural populations. Many stations also showed differentiation from their corresponding natural populations. Replacing the existing station broodstock might not be desirable since stations also produce fingerlings for aquaculture and their stocks might already have adapted for aquaculture conditions.

It is important that fisheries stations clarify the objectives of their fingerling production, i.e., for aquaculture or for restocking programs. Establishing specific stocks for releasing purpose is recommended for stations that are responsible for restocking of the species in native watersheds. These stocks should be a collection of natural populations within a watershed.

Transferring stock across watersheds, even small numbers, may lead to an altered genetic make up of the natives of watersheds

Research should also be continued to identify other natural populations. Both the Chao Phaya and MaeKlong rivers consist of numerous tributaries, the present survey has only covered the main rivers, where the restocking is intensive. Further investigation of *P. gonionotus* populations in such tributaries may lead to discovery of more distinct genetic groups which are valuable resources that can be used as broodstock both for restocking within each watershed and for aquaculture purposes.

Interdisciplinary research team in Northeast Thailand

background

The interdisciplinary research on "Genetic Diversity in Aquaculture: Economically and Socially Sustainable Conservation in Northeast Thailand" was developed on the assumption that an attempt to understand genetic quality, diversity and improvement would not feasible and acceptable without considering them in their social and economic circumstances. The research, therefore, aimed to examine not only the differences of genetic and growth performance of Puntius, the sample species, but also the potential genetic effect of social and economic aspects of Puntius production and distribution. Undoubtedly, there are a number of factors contributing to biodiversity and quality of existence of which was discovered by the research team), a key distribution mechanism of Puntius. However, this work focused upon one in particular; the mobile trading system (the fingerlings in Northeast Thailand particularly in Khon Kaen Province.

The mobile trading system

The mobile trading system is a strategy in which dealers bring commodities to sell to consumers in their villages. Although mobile trade of a variety of consumer goods originated a few decades ago, only in the past five years has this strategy been used to sell fish fingerings. Farmers interviewed in this study were often unable to obtain fingerlings since the demand usually exceeds the supply. In this situation, the mobile trading system has served as a distribution mechanism which responds to the limitation of aquaculture development.

Flows of fingerlings and fish in all models are one way, that is the systems exhibit open flow. Flows start from the hatchery and move towards the consumers. None of the hatcheries included in this study select their stocks from grow-out farms with in their own network, rather brooder stocks have been exchanged among the hatcheries. The pattern of fingerling/fish flows imply that among different groups of people who have involved in fish culture, the breeders are the most influencing group on genetic quality and biodiversity in aquaculture.

All five hatcheries obtained fish stocks from more than one source. Grow-out farmers of all networks may or may not always use the same source of supply. This means that some grow-out farmer may buy fingerlings from the same the hatchery for some years while others may change hatcheries from year to year. Some may buy fingerlings from different sources within a single years.

The reputation of hatcheries as perceived by their customers is also significant. However, the customer's perception in this regard does not correspond to genetic results. Fingerlings that are produced by the most successful hatchery are the poorest quality (in terms of microsatellite DNA parameters) among the five hatcheries included in this study. From this case, then, "reputation" may have nothing to do with genetics.

Mobile traders as intermediaries also deal with grow-out farmers. All mobile traders mentioned that they try to provide their customers with quality fingerlings so that they can return to sell fingerlings in the same village in the coming years. Grow-out farmers, however, commented negatively on quality, in terms of low survival and growth rates, small size of fry as well as a mixture of unwanted fish. Some farmers who have had negative experiences in obtaining fingerlings from mobile traders stated that they wish to try to buy fingerlings directly from hatcheries to get good quality at a reasonable price. Nevertheless under conditions of over demand and a short growing season, farmers do not have much choices other than to rely on the mobile traders. The situation is more critical for those who live in remote areas and have to travel considerable distances to the hatchery.

The important point that should be made here is that the relationships among different groups of people in the networks influence the genetic system. As discussed earlier, some mobile traders have chosen hatcheries in response to feedback from farmers even when demand exceeds supply. In addition, farmers are willing to and do pay for good quality fingerlings. The effects of this selection process on genetic quality and diversity are not yet obvious under the conditions in which supplies are short and flows of fingerling/fish in the networks are one way. However, the intensity of social and economic selection process on genetic system can be assessed.

Influence of mobile trading system on genetic quality and biodiversity in aquaculture

It is obvious from the previous discussion that the mobile trading system has increased fingerling availability for grow-out farms which also has an impact on fish traders and consumers. This conclusion is also valid where the demand of fingerlings exceeds supply. However if the ratio of demand and supply is more balanced, we may expect to find a higher degree of species diversity and genetic quality within species.

The grow-out farmer may deal with different hatcheries, through different mobile traders, which are perceived to provide good quality fingerlings. Therefore, mobile trading system can influence selection among or between breeds. However, the system can also work against the conservation between breed diversity if only one kind of breed is developed and propagated.

Unlike fish flow, Information flow within the networks is two way. Mobile traders have received complaints from their customers about quality of fingerlings and the traders have passed these complaints back to the breeders. In some cases the breeders have directly received feedback from grow-out farmers. This is confirmed by the breeders. This feedback can potentially influence the genetic quality of fish. Nevertheless, this feedback information has not been realised by the breeders because of the imbalance of demand and supply.

Policy implications

The genetic analysis performed by Dr. Kamonrat has shown that in existing situation genetic diversity within the population is high. In other wards, we may also say that the networks of fingerling distribution, both mobile trading and the membership systems, have maintained genetic diversity within particular populations.

The conclusion is clear at this point is that mobile trading can potentially influence genetic quality and biodiversity in aquaculture when demand exceeds supply. Although the system can have only a limited effect on genetics in the short term, it has the potential to influence the genetic system.

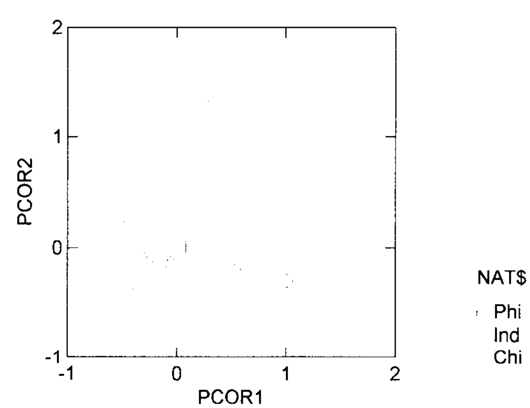
CHINA

background

Six local strains or "landraces" of common carp were examined (three in detail) in Jiangxi province, China, during the summer of 1994. Genetic data analyses were performed at the Marine Gene Probe Laboratory by Ms. Shi Yonghong of the FFRC. The FFRC and Shanghai teams in China have concluded that conserving this diversity during the modernization of Chinese society will require retaining and even promoting traditional cultural beliefs about the value of fish. The goal is to ensure that small-hold farmers can profitably cultivate these strains for local consumption or wider distribution.

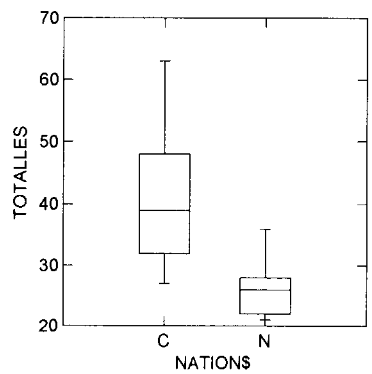
levels of genetic differentiation

The study has shown that China has a rich genetic biodiversity of common carp. In the figure below, the genetic diversity of the carp samples taken in this study is summarized by principal coordinate analysis.



The first two coordinates, which encompass approximately 40% of the total variation, are plotted against each other. It can be seen that the populations from China (open circles) extend over a much wider range of genetic space than the samples from Indonesia (X) which cover a similar geographical area. The sole sample from the Philippines (a cross) is intermediate, which is consistent with the known history of stock transfer of common carp.

Another indication of the importance of China as a reservoir of genetic diversity is the total number of alleles in the populations sampled in China (C) and Indonesia (N) as shown in the figure below.



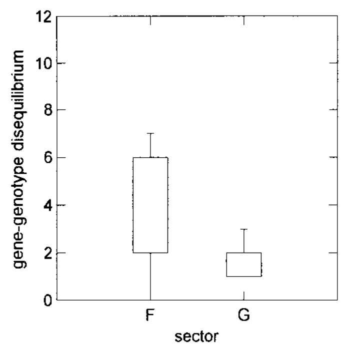
conservation and development of genetic quality

In China, a highly successful farmer-participatory information and training network has been established.

This farmer network, already established by the Freshwater Fisheries Research Center, will provide community-designed and community-motivated evaluation of local strains in terms of traditional perceptions of quality and usefulness, and evaluation of the feasibility of simple breed improvement procedures for small-hold farmers. In its expanded form it will include farmers from a variety of ethnic, social, geographic and economic groupings as well as others in the community (media people, for example) who can influence the cultural appreciation of various strains.

The farmer network will cooperate with FFRC research staff in the design and testing of broodstock management procedures for their local strains, after the conclusion of the current project. The researchers will ensure that the procedures are technically effective, while participation by the farmers will ensure that the procedures are socially acceptable and economically sustainable (i.e., profitable) in their communities.

The strong socio-economic influence on management can be seen in the figure below, in which the genetic quality of samples taken from two types of institutions are compared. The measure of quality is "gene - genotype disequilibrium" (Hardy-Weinberg disequilibrium). Government Institutions (G) have a considerably lower level of disequilibrium than the private sector farms (F). This is a clear indication that the farmers are mixing up their populations and/or maintaining exceedingly low population sizes.



Policy implications

From the figures above it is clear that the populations of carp in Indonesia, China and the Philippines do not overlap in the genetic coordinate system developed with the data collected in this project. Of course the samples are very limited in size and geographic coverage, but it does suggest that *the primary level of conservation (among the populations thus far sampled), should be between nations.*

It is also clear that the recent privatization of the Chinese fish culture industry is having the unfortunate (for conservation of genetic biodiversity) effect of *breaking down the management of traditional strains as unique, viable genetic units in Government hatcheries.*

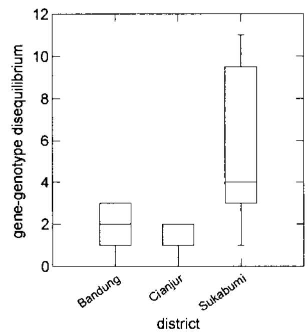
INDONESIA

background

More than 80 aquaculture sites in West and Central Java were studied by the Indonesian project team using RRA-based techniques. Genetic samples were obtained from many of these farms and analysed by Ms Shi Yonghong in the Marine Gene Probe Laboratory. As in China, the DNA samples obtained from local farm broodstock are showing highly significant patterns of diversification and inbreeding.

There is no ongoing conservation program except for small ex situ collections at the Research Institute for Freshwater Fisheries and several strains preserved by the preferences of local Indonesian people. The genetic and socioeconomic data from this project are currently being correlated and analysed statistically, but a number of points are already clear. Perhaps the most important of these is the demonstration of the impact of the economic (marketing) system on the genetic quality of common carp in Indonesia.

In the figure below, the gene-genotype (Hardy-Weinberg) disequilibrium values are shown for the samples taken from the three regencies studied in Java. It can be seen that the level of disequilibrium (a measure of genetic mixing and/or low effective population size) is much higher in the Sukabumi regency. Paradoxically, Sukabumi is the regency which has the best-organized and centralized marketing system for the fish "seed" used for growout by fish farmers. The most likely interpretation of these data is that the marketing system is mixing the strains up and compromising the genetic integrity of the locally adapted populations



Policy implications

The Phase II plan for Indonesia involves participatory research with traditional social groupings such as the gotong-royong and nyambot (volunteer associations of men and women) and farm groups such as Kelompak Tani and Klompencapir whose purpose is primarily educational. The productivity and economic value of traditional strains will be established to the satisfaction of the farmers through cooperative arrangements among breeders and users of carp "seed". This community-level evaluation programme will be back-stopped by a planned programme to certify farmers who follow acceptable standards of broodstock maintenance, and to certify strains that meet agreed standards of perceived appearance, genetic quality and economic and social value.

Follow-up plans

Research

The IDRC-supported project has ended, but a number of follow-up activities are known to be under way without IDRC involvement:

In China, the FFRC (Professor Zhang's group) is participating in an Asian Development Bank project on the conservation and improvement of Common Carp.

In Malawi, Chancellor College (Dr. Ambali's group) has been awarded Rockefeller and JICA grants to set up a regional laboratory for DNA analysis and to continue and expand the work on aquaculture genetic development and conservation.

In Thailand, researchers from Chulalongkorn University (Dr. Anchalee, trained at the MGPL) and the Aquaculture Genetics Research Institute (Drs. Kamonrat and Uraiwan) are collaborating on research projects and research grant proposals in the area of aquaculture genetics. The association with the MGPL (Doyle) is continuing

Publication

There are approximately 15 English-language manuscripts prepared by the Canadian, Asian and African participants in the project. Several (at least 4) of these have been submitted for publication in international journals. The remaining publications will receive final editing by R. Doyle in May 1997, while he is a visiting fellow at FAO in Rome. The results of the project as a whole will be summarized and synthesized as an output of that fellowship in the form of an FAO or joint FAO/IDRC publication.