

Assessment of freshwater fish seed resources for sustainable aquaculture



Cover photos:

Left: Freshwater fish seed production activities: hapa system used in fish seed nursery, Cambodia (courtesy of So Nam).

Right, top to bottom: Sacrificing male catfish to obtain milt, Cameroon (courtesy of Randy Brummett); careful selection of broodfish for spawning, Viet Nam (courtesy of Pham An Tuan).

Assessment of freshwater fish seed resources for sustainable aquaculture

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Preparation of this document

Under the Aquaculture Management and Conservation Service (FIMA) Regular Programme (RP232A1001409), a project Study and Analysis of Seed Production in Small-scale Rural Aquaculture was undertaken from 2005–2006. The project consisted of a desk study (country-level assessment, regional syntheses and thematic reviews on freshwater fish seed resources and production) and an FAO Expert Workshop on Freshwater Fish Seed as Global Resource for Aquaculture (held in Wuxi, China, from 23 to 26 March 2006). The project culminated in the publication of this document which is presented in two parts.

The study and expert workshop were technically supervised by Dr Melba B. Reantaso, Fishery Resources Officer of FIMA, Fisheries and Aquaculture Management Division (FIM) of FAO Fisheries and Aquaculture Department.

Twenty-one aquaculture experts contributed to Part 1 of this document which contains the proceedings and recommendations of the expert workshop. Thirty-five specialists on various aspects of aquaculture contributed to Part 2 of this publication comprised of 21 country case studies, three regional syntheses and eight thematic reviews and contributed papers. The country case studies followed a template and include: (a) introduction, (b) seed resources and supply, (c) seed production facilities and seed technology, (d) seed management, (e) seed quality, (f) seed marketing, (g) seed industry, (h) support services, (j) legal and policy framework, (l) information or knowledge gaps, (m) stakeholder and (n) future prospects and recommendations.

Abstract

Four of the most important resources to aquaculture, outside human and technological resources, are land, water, seed and feed. Efficient use of these resources are necessary to guarantee optimum production from aquaculture. A number of regional and international events highlighted some of the most pressing issues concerning seed in global aquaculture development. These include inadequate and unreliable supply of quality seed, genetic quality, inadequate hatchery technology and facilities for rearing fry/fingerlings, distribution mechanisms, impacts of releases of cultured seed stocks, the need for more hatcheries with business orientation and others. In order to secure stable seed supply for major freshwater aquaculture species, factors affecting seed availability, seed quality, seed production technologies and support services, seed distribution networks, breeding technologies, genetic improvement and domestication need to be understood well if resources are best to be targeted and policy decisions on future investment and management options improved.

Recognizing these issues, a project Study and Analysis of Seed Production in Small-scale Rural Aquaculture was undertaken by the Aquaculture Management and Conservation Service of FAO's Department of Fisheries and Aquaculture. The project was implemented through a desk study and an expert workshop to assess the status of freshwater fish seed resources and supply and its contribution to sustainable aquatic production. The desk study, undertaken between July 2005 and April 2006, consisted of: (i) country-level assessment, (ii) regional syntheses and (iii) thematic reviews. The FAO Expert Workshop on Freshwater Seed as Global Resource for Aquaculture, held in Wuxi, China, from 23 to 26 March 2006 and hosted by the Wuxi Freshwater Fisheries Research Center, Chinese Academy of Fisheries Sciences, was aimed at analysing the current status of the freshwater seed sector used in aquaculture with special emphasis on rural aquaculture and evaluating the current constraints and challenges as basis for identifying measures and generating action that will contribute to the sustainable development of this sector.

This publication is presented in two parts. Part 1 contains the proceedings and major recommendations of the expert workshop which tackled three major themes: (1) seed quality, genetics, technology and certification; (2) seed networking, distribution, entrepreneurship and certification; and (3) how rural fish farmers can benefit from the freshwater aquaseed sector. Part 2 contains the detailed outcomes of the desk study consisting of three regional syntheses (Africa, Asia and Latin America) based on 21 country case studies (Bangladesh, Brazil, Cambodia, Cameroon, China, Colombia, Cuba, Ecuador, Egypt, Ghana, India, Indonesia, Mexico, Nigeria, Pakistan, the Philippines, Sri Lanka, Thailand, Uganda, Viet Nam and Zimbabwe), five thematic reviews (seed quality, genetics and breeding in seed supply for inland aquaculture, seed networks and entrepreneurship, role of seed supply in rural aquaculture, farmer innovations and women involvement in seed production) and three invited papers (self-recruiting species, decentralized seed networking in Bangladesh and establishment of national broodstock centres in Viet Nam).

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Executive summary

A project Study and Analysis of Seed Production in Small-scale Rural Aquaculture was implemented through a desk study and an expert workshop to assess the status of freshwater fish seed resources and supply and its contribution to sustainable aquatic production. The study, undertaken between July 2005 and April 2006, consisted of: (i) country-level assessment, (ii) regional syntheses and (iii) thematic reviews on issues affecting the freshwater fish seed production sector. The project included the FAO Expert Workshop on Freshwater Seed as Global Resource for Aquaculture aimed at analyzing the current status of the freshwater seed sector used in aquaculture with special emphasis on rural aquaculture and evaluating current constraints as basis for identifying measures and generating action to address such challenges. The expert workshop was held in Wuxi, China from 23 to 26 March 2006 and hosted by the Wuxi Freshwater Fisheries Research Center of the Chinese Academy of Fisheries Sciences.

This publication is presented in two parts. Part 1 contains the proceedings and recommendations of the expert workshop which tackled three major themes, namely: (1) Theme 1 on seed quality, genetics, technology and certification; (2) Theme 2 on seed networking, distribution, entrepreneurship and certification and (3) Theme 3 on how rural fish farmers can benefit from the freshwater aquaseed sector. Part 2 presents the detailed outcomes of the desk study consisting of three regional syntheses (Africa, Asia and Latin America) based on 21 country case studies (Bangladesh, Brazil, Cambodia, Cameroon, China, Colombia, Cuba, Ecuador, Egypt, Ghana, India, Indonesia, Mexico, Nigeria, Pakistan, the Philippines, Sri Lanka, Thailand, Uganda, Viet Nam and Zimbabwe), five thematic reviews (seed quality, genetics and breeding in seed supply for inland aquaculture, seed networks and entrepreneurship, role of seed supply in rural aquaculture, farmer innovations and women involvement in seed production) and three invited papers contributed during the expert workshop (self-recruiting species, decentralized seed networking in Bangladesh and establishment of national broodstock centres in Viet Nam).

On key issues concerning Theme 1, the expert workshop recommended for concerned authorities and FAO to: (a) assist member countries in the development of national broodstock certification programs (at national level) including provision of guidelines on development of national broodstock certification systems for public and/or private sector seed suppliers; (b) support the development of guidelines for establishing standardized protocols to optimize seed quality and certify hatcheries at national level; (c) review models used for certification in the livestock sector (and possibly agriculture sector in general) particularly on processes involved in developing certification systems for seed quality; (d) support regional multi-disciplinary reviews of broodstock quality of key freshwater aquaculture species being transferred regionally and internationally; (e) develop species- and/or system-specific checklists on seed quality for use by purchasers at the point of sale and (f) review the potential impact of past and current culture-based fisheries on genetic diversity of wild stocks in major regional watersheds.

Concerning Theme 2, major recommendations to concerned authorities and FAO include: (a) development of technical guidelines on registration, licensing and/or certification and provision of assistance in the implementation of such guidelines; (b) compile a set of best practices implemented in various countries, including models and options for networking and partnerships, based on lessons learned; (c) encourage the establishment of international networks for collaboration in genetic improvement, sharing of information and genetic material; (d) support the development and/or updating

of training and extension materials related to seed production and distribution and (e) conduct livelihood analysis of people in rural communities involved in various activities of seed production and distribution to generate information for policy development.

On key issues pertaining to Theme 3, major recommendations include: (1) provision of capacity building activities in the following areas: (i) seed nursing, entrepreneurship and credit and savings management (targetting women); (ii) simple hands-on and practical training on various aspects of seed production (e.g. breeding; nursing; stress tests; simple seed quality test, basic health checks; conditioning, packaging and transporting; record keeping and basic accounting or simple bookkeeping and simple understanding and managing of risks) for rural fish farmers and hatchery/nursery operators and traders; (2) support a regional project to focus on enhancing the role and empowerment of women in aquatic food production with emphasis on skills development and organization of women into Self-Help Groups (SHG); (3) conduct sustainability studies using Farmer Participatory Research (FPR) in places where Farmer Field Schools (FFS) have been practiced in rural aquaculture (e.g. Bangladesh, Indonesia and Viet Nam), taking experiences and lessons learned and particularly incorporating seed production in the system; (4) review and compile all relevant published materials on indigenous knowledge and farmer innovations and document other unpublished practices; and (5) create a database of farmer innovations and make it accessible to all.

The desk study revealed that harvests from freshwater aquaculture will continue to substantially contribute to global aquatic production. The 21 country case studies were unanimous in their findings that the freshwater seed sector is one of most essential and profitable phase in aquaculture production. Efficient use of freshwater fish seed resources will be necessary to guarantee optimum production from aquaculture.

In Africa, availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture. Government hatcheries have generally failed to achieve sustainability and the private sector is impeded by the lack of marketing information and appropriate technological assistance. At present, the main aquaculture species in the continent are Nile tilapia (*Oreochromis niloticus*) and the African sharptooth catfish (*Clarias gariepinus*). While the tilapias are easy to reproduce on-farm, poor broodstock management had resulted in reduced growth rates in many captive populations. Catfish are mostly reproduced in hatcheries, but availability of broodstock and high mortality rates in larvae are key problems still requiring research. Of the countries reviewed, Egypt (1.2 billion tilapia and 250 million carp fingerlings produced) and Nigeria (30 million fingerlings produced) report the highest number of modern private commercial hatcheries, although most of these are unregulated and lack accreditation and certification systems. Ghana, Cameroon, Uganda and Zimbabwe rely almost entirely on semi-commercial systems producing unreliable quantities and quality of seed. Interventions to improve the quality of extension services, make credit more available and build partnerships between public and private sectors to address key researchable topics are recommended to improve the availability of fish seed to African fish farmers.

In Asia, even though seed of major cultivated species are produced in sufficient quantities in hatcheries, poor quality is perceived as a major constraint to expansion of freshwater aquaculture. Several approaches ranging from institutional to farmer-managed decision-making tools have been adopted by countries and farmers to assure fish seed quality. The regional focus has shifted from centralized to decentralized seed production, a strategy which offers opportunities for poor farmers to enter into the fish seed business. Decentralized fish seed production should be supported by appropriate breeding strategies to maintain the genetic quality of broodstock. Building support services at the local level is crucial in expanding fish seed supply. With basic technologies for small-scale fish breeding and fry nursing largely in place, future support should now focus on extension of knowledge and building of institutional

support for rural households where there is potential for fish breeding and fry nursing. Information sharing mechanism on hatchery breeding and fry/fingerling production as an agribusiness will also help enhance capacities in countries where these technologies are still not well-developed.

In Latin America, Chile, Brazil, Mexico and Ecuador produce more than 80 percent of the total regional aquaculture production. The overall growth of the freshwater aquaculture industry demands for an increasing and stable supply of reliable and traceable seed to sustain regular production. Such factors are critical to sector sustainability and the issues have been approached firstly by governments and later by farmers themselves. As the aquaculture sector grew and turned into an export-oriented industry, private investment has been channeled into seed production, either as an exclusive activity, or as a part of vertically-integrated aquaculture ventures. Seed quality parameters (i.e. survival, growth rate, disease resistance, size homogeneity) within countries, have historically been indirectly measured through the level of satisfaction of seed buyers and are not regulated by governments. However, with increasing international seed trade, regional hatcheries are slowly introducing quality assurance measures, both as part of hatchery operation procedures and genetic manipulation of their broodstock. The only type of certification that is common to all countries of the region is an official zoosanitary certificate that is mandatory before domestic and international movement of organisms can take place. Given the rapid expansion of export-oriented culture of high-value species, it is expected that both volume of high quality seed and quality certification procedures will gradually be in place throughout the region.

In order for the sector to develop in a sustainable manner, an enabling environment will be required in terms of basic production and human infrastructure, financial/business/marketing support and policy and legal frameworks. Severe challenges will be faced concerning water allocation and land use for general aquaculture production and as such the following areas below need careful consideration to enhance the development of the freshwater seed production sector to support aquaculture sustainability.

Seed quality is an essential attribute to optimize the potential for aquaculture production (better yield and good returns) and is related to the quality of the broodstock used and the seed produced. Genetic quality and good hatchery/nursery management are two main factors affecting seed quality. It is important to understand the factors that contribute to poor quality seed and to develop interventions (e.g. better management practices) to address the problem. In many aquaculture systems, stocking quality seed does not necessarily ensure a successful crop. Seed certification and accreditation of practices should be continuously explored.

Approaches to genetic improvement using successful research findings (e.g. selective breeding, application of genetic markers, sex control techniques, chromosome set manipulation, crossbreeding and transgenesis) should be integrated with good genetic management during domestication and translocation of aquaculture stocks. In addition, such approaches should be supported by efficient and equitable dissemination and technology transfer strategies coupled with awareness and/or certification programs. Strengthening awareness and institutional capacity to deal with ecological risks associated with introductions of alien and/or genetically improved fish will be essential. Use of indigenous species and their domestication for freshwater aquaculture production should be promoted.

Seed certification is a quality assurance system aimed to produce and supply high quality seed to farmers. It is a system which meets certain minimum pre-determined quality standards and criteria, e.g. genetic purity, appropriate husbandry, high grow-out performance, freedom from major diseases, other market needs, etc. A process which adds value to the potential of aquaculture production, seed certification will outweigh the anticipated increased costs when done properly. Seed certification is part of a wider programme on genetics and breeding, biodiversity conservation and international trade.

There are various levels of success on seed certification used for freshwater aquaculture seed. There is value in reviewing certification models used in the livestock and plant sectors to determine which processes can be adapted for use in aquaculture.

The main actors in a freshwater seed network are the breeders, hatchery and nursery operators, traders, growers and other input/service providers (e.g. water suppliers, transport providers, hormone sellers, nightsoil traders, extension workers, etc.). Seed networking has become an important component of the sector that enabled accessibility and delivery of fish seed in areas distant from traditional sources, thus, stimulating aquaculture development in marginal and remote rural areas. Seed networking should be promoted and supported with enabling policies and required infrastructure.

Broodstock management will be a key issue in meeting the projected fingerling requirement to 2020. To meet this challenge, there is a need for a shift in freshwater aquaculture technology from intensive-water use of land-based systems to water-saving and water productivity-enhancing interventions. Integrating fish seed production with agriculture and optimizing the use of irrigated agricultural land, as seen in several countries, can be further explored. The use of cages and *hapas* for fry- to fingerling-rearing is becoming increasingly popular in some countries, particularly those which have large numbers of perennial water bodies. Such initiatives contribute to the enhancement of productivity of irrigation water bodies and enable landless households to generate income and animal protein from fish culture activities provided there is equal access to such resources.

Many rural farmers have developed technology innovations and applied indigenous knowledge in order to meet their livelihood necessities. In aquaculture seed production sector, some examples include the following: (1) hatchery technology (bamboo/wood-based circular technology), (2) breeding techniques (Bundh breeding in India), (3) nursing techniques (removal of egg stickiness by washing with milk prior to nursing in jars, application of fermented manure including oil cakes, stunting fish technology), (4) local methods for fish collection and transportation and others. Many such innovations and indigenous knowledge remain undocumented. Reviewing and compiling all relevant published materials on indigenous knowledge and farmer innovations, documenting other unpublished practices, creating a database on farmer innovations and making it accessible to all, replicating and promoting fully-tested innovations in other countries/regions and giving recognition to successful farmer innovators are suggested actions to enhance available human capital.

Private-public sector partnership can be tapped by improving integration and linkages of inputs and efficient delivery of services of the broad spectrum of the freshwater fish seed production sector, for example: (a) large-scale hatchery operators supporting small-scale operators on training, information sharing, broodstock exchange and provision of high quality seed; (b) promoting government-private sector (large hatcheries) partnership for broodstock development and (c) promoting contract growing for fingerling production as practiced in China.

Aside from enabling policies, there are many strategic elements and approaches which can be promoted to enhance the benefits to and participation and contribution of small-scale farmers. These include: (i) practical application of the concepts of FFS, FPR and training of trainers; (ii) providing good access to rural microfinancing programmes; (iii) supporting formation of SHGs and producer associations; (iv) harnessing farmer innovation and indigenous knowledge; (v) building capacity on community-based aquatic resource management; and (vi) communicating the various risks in aquaculture production.

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Acronyms and abbreviations

AAI	Aquaculture Authority of India
ABRACOA	Brazilian Association for the Culture of Aquatic Organisms
ABRAQ	Brazilian Aquaculture Association
ABRAS	Brazilian Supermarket Association
ACIAR	Australian Centre for International Agricultural Research
AD	Aquaculture Division (Department of Fisheries, Cambodia)
ADB	Asian Development Bank
ADP	Agricultural Development Programmes
AEO	Aquaculture Extension Officers
AFFAN	Association of Fish Farmers and Aquaculturists of Nigeria
AFLPs	amplified fragment length polymorphisms
AFGRP	Aquaculture and Fish Genetic Research Programme
AFP	anti-freeze protein gene
AGCD	General Administration for Development Cooperation
AGIP	Azienda Generale Italiana Petroli
AIFP	Aquaculture and Inland Fisheries Project
AIMS	Aquaculture of Indigenous Mekong Species (Cambodia)
AIT	Asian Institute of Technology
AKVAFORSK	Norway Institute of Aquaculture Research
AOFFN	Association of Ornamental Fish Exporters of Nigeria
APFON	Association of Fingerling Producers of Nigeria
APHEDA	Australia People for Health Development Abroad
APIP	Agriculture Productivity Improvement Project (Cambodia)
AQDC	Aquaculture Development Center (Sri Lanka)
ARDQIP	Aquaculture Resource Development and Quality Improvement Project (Sri Lanka)
AREX	Agriculture and Rural Extension
ASA	Association for Social Advancement
AUSAID	Australian Agency for International Development
BAU	Bangladesh Agricultural University
BCIS	Beijing Consensus and Implementation Strategy
BDT	Bangladesh Taka
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BFRI	Bangladesh Fisheries Research Institute
BFSPRC	Bati Fish Seed Production and Research Center (Cambodia)
BMPs	Better management practices
BRAC	Bangladesh Rural Advancement Committee
BRL	Brazil Real
CAFAN	Catfish Farmers Association of Nigeria
CaO	calcium oxide, quicklime
CARD	Collaboration for Agriculture and Rural Development Programme
CARE	Cooperative for Assistance and Relief Everywhere
CARFSPS	Chak Ang Rae Fish Seed Production Station (Cambodia)
CARITAS	Catholic Agency for International Aid and Development
CAUNESP-UNESP	Aquaculture Center of the São Paulo State University

CBFM	Community-based Fisheries Management
CBOs	Community-based Organizations
CCFRS	Chrang Chamres Fisheries Research Station (Cambodia)
CCRF	Code of Conduct for Responsible Fisheries (of FAO)
CDRMP	Community Development and Resource Management Project
CENIACUA	National Center of Investigations in Aquaculture (Colombia)
CEPAM	Aquaculture Training Centre of Mamposton (Cuba)
CEPTA	Aquaculture Research and Training Center (Brazil)
CFA	Central African Franc
CGIAR	Consultative Group on International Agricultural Research
CGHV	Grass carp hemorrhagic virus
CIFA	Central Institute for Freshwater Aquaculture
CIFE	Central Institute of Fisheries Education
CIFRI	Central Inland Fisheries Research Institute (India)
CLSU	Central Luzon State University (CLSU)
CMFRI	Central Marine Fisheries Research Institute (India)
CNY	China, Yuan Renmindi
COA	Commission on Audit
CoC	Code of Conduct
COD	Carbon oxygen demand
CODEVASF	Company for the Development of the São Francisco Valley (Brazil)
CONAMA	National Council for Environmental Affairs (Brazil)
CoP	code of practice
COP	Colombian peso
CP	Charoenpokaparn Company Ltd.
CP	culture pond
CRS	Catholic Relief Services
CSIR	Council of Scientific and Industrial Research (India)
CY	Calendar Year
CUC	Cuba Convertible Peso
DANIDA	Danish International Development Agency
DMMSU	Don Mariano Marocs Memorial State University
DNA	deoxyribonucleic acid
DNOCS	National Department of Engineering Against Droughts
DFID	Department for International Development of the United Kingdom
DFRRI	Directorate of Food, Roads and Rural Infrastructure
DOCA	deoxycorticosterone acetate
DoF	Department of Fisheries (Cambodia)
DOF	Department of Fisheries (Bangladesh)
DOF	Department of Fisheries (Thailand)
DoF/AIT-AARM	DoF/AIT Aquaculture and Aquatic Resources Management
DoF/MRC-READ	DoF/MRC Rural Extension for Aquaculture Development
EED	Exuvia entrapment disease
EEZ	Exclusive Economic Zone
EGP	Egypt Pound
EIA	environmental impact assessment
ELISA	Enzyme-Linked Immunosorbent Assay
EOS	Extension Officers
EPC	Extract of Pituitary of Carp
ESALQ-USP	Superior School of Agriculture Luis de Queiroz from the University of São Paulo in Piracicaba

ESC	Exotic Species Center
ESPC	Exotic Species Production Center
EU-PRASAC	EU-Pole regional de recherche appliquee au developpement des savanes d'agriculture centrale
EUS	Epizootic ulcerative syndrome
F1	Filial 1, the first filial generation seed/plants or animal offspring resulting from a cross mating of distinctly different parental type
FAC	Freshwater Aquaculture Center (CLSU)
FAG	Farming Guaranty Funds (Colombia)
FAIEX	Freshwater Aquaculture Improvement and Extension Project (Cambodia)
FAO	Food and Agriculture Organization of the United Nations
FAO-RAF	FAO Regional Office for Africa
FAO-RAP	FAO Regional Office for Asia and the Pacific
FARMC	Fisheries and aquatic resource management councils
FAO-RLC	FAO Regional Office for Latin America and the Caribbean
FASA	Faculty of Agronomy and Agricultural Sciences
FaST	FAC-Selected Tilapia
FDA	Food and Drug Administration (United States of America)
FDAP	Fisheries Development Action Plan
FDF	Federal Department of Fisheries (Nigeria)
FEDEACUA	Colombian Federation of Aquafarmers
FFDA	Fish Farmers Development Agency
FFS	Farmer field schools
FIES	Fisheries and Aquaculture Information and Statistics Service
FIMA	Aquaculture Management and Conservation Service
FINAGRO	Financing Funds of Sector Agropecuario (Colombia)
FISON	Fisheries Society of Nigeria
FLD	Farmer Livelihood Development (Cambodia)
FMAS	farmer-managed aquatic systems
FMRT	Fisheries and Marine Resource Technology
FSPRS	Fish Seed Production and Research Stations (Cambodia)
FSPS	Fishery Sector Programme Support
FRSS	Fisheries Resource Survey System (Bangladesh)
GAFRD	General Authority for Fish Resources Development
GAP	Good Aquaculture Practices
GAVS	General Authority for Veterinary Services
GBC	Genetic Breeding Center
GCHV	Grass carp hemorrhagic virus
GDP	Gross domestic product
GEF	Global Environmental Facility
GET EXCEL	Genetically Enhanced Tilapia – and Excellent strain that has Competitive advantage for Entrepreneurial Livelihood projects
GFSMF	Government Fish Seed Multiplying Farms
GH	growth hormone gene
GHC	Ghana Cedi
GIAN	Grassroots Innovation Augmentation Network (India)
GIFT	Genetically Improved Farmed Tilapia
GIFT FI	GIFT Foundation, Incorporated
GMF	Grammen Matsha Foundation
GMT	Genetically Male Tilapia

GMO	genetically modified organisms
GOV	Government of Viet Nam
GSI	Genetic stock identification
GST	Genomar Supreme Tilapia
GTZ	German Technical Cooperation
GURT	genetic use restriction technologies
HACCP	Hazard Analysis and Critical Control Point
HCG	Human Chorionic Gonadotropic
HH	High Health
HHP	household pond
IAGA	International Association for Genetics in Aquaculture
IAS	Institute of Aquaculture, Stirling University
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
ICA	Colombian Institute of Agriculture and Livestock
ICAR	Indian Council of Agricultural Research
ICES	International Council for the Exploration of the Seas
ICLARM	International Center for Living Aquatic Resources Management
IDA	International Development Association
IDR	Indonesian Rupiah
IDRC	International Development Research Centre (Canada)
IFReDI	Inland Research and Development Institute (Cambodia)
IIM	Indian Institute of Management
IITA	International Institute for Tropical Agriculture
IMC	Indian major carps
IMNV	idiopathic muscle necrosis virus
INCODER	National Institute for Rural Development (Colombia)
INPA	National Institute of Fisheries and Aquaculture (Colombia)
INR	Indian Rupee
IOs	international organizations
IPM	Integrated Pest Management
IPN	infectious pancreatic necrosis
INR	Indian Rupee
IRAD	Institute of Agricultural Research for Development
IRR	Internal Rate of Return
IVA	Tax Valor Agregado (Colombia)
IVLP	Institute Village Link Programme
JICA	Japanese International Cooperation Agency
KHR	Cambodia Riel
KMNO ₄	potassium permanganate
KVK	Krishi Vignana Kenddra
LAPAD-UFSC	Freshwater Fish Aquaculture Laboratory from the Federal University of Santa Catarina
LH-RH	Luteinizing hormone releasing hormone
LGC	Local Government Code
LGU	Local Government Unit
LHA	Lake Harvest Aquaculture
LKR	Sri Lankan Rupee
MAFF	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
MAPA	Ministry of Agriculture, Supply and Cattle (Brazil)
MAS	marker assisted selection
MBV	monodon baculovirus

MCAC	<i>Mission française de coopération et d'action culturelle</i>
MEP	Ministry of Economy and Planning
MINEPIA	Ministry of Animal Industries and Fisheries
MINRESI	Institute for Agricultural Research for Development
MIP	Ministry of Fisheries (Cuba)
MCC	Mennonite Central Committee
MMV	<i>Macrobrachium</i> muscle virus
MINSAP	Institute of Hygiene and Epidemiology of the Ministry of Public Health (Cuba)
MOA	Memorandum of Agreement
	Ministry of Agriculture (China)
MOFI	Ministry of Fisheries (Viet Nam)
MoFL	Ministry of Fisheries and Livestock (Bangladesh)
MPEDA	Marine Products Export Development Authority
MRC-AIMS	Aquaculture of Indigenous Mekong Species of the Mekong River Commission
MrNV	<i>Macrobrachium rosenbergii</i> nodavirus
mtDNA	mitochondrial DNA
MS 222	tricaine methane sulfonate
MSc	Master of Science
MXN	Mexican Peso
NA	Northern Areas
NAADS	National Agriculture Advisory Services (Uganda)
NABARD	National Bank for Agriculture and Rural Development
NABWSS	National Aquatic Bred and Wild Seed System (China)
NACA	Network of Aquaculture Centres in Asia-Pacific
NACRDB	Nigeria Agricultural Cooperative and Rural Development Bank
NAFEC	National Fishery Extension Centre
NAQDA	National Aquaculture Development Authority of Sri Lanka
NARS	National Agricultural Research Systems
NASPS	National Aquatic Seed Production System
NAWCP	National Aquatic Weed Control Project
NBC	National Broodstock Center (Philippines)
NBC	National Broodstock Centre (Viet Nam)
NBFRG	National Bureau of Fish Genetic Resources
NCCA-WBV	National Certification Committee of Aquatic Wild and Bred Varieties
NCDC	National Cooperative Development Cooperation
N_e	effective population size
NEPAD	New Partnership for Africa's Development
NET	northeast Thailand
NGOs	Non-governmental Organizations
NGN	Nigerian Naira
NEFP	Northwest Fisheries Extension Project (Bangladesh)
NFFTC	National Freshwater Fisheries Technology Center (Philippines)
NIF	National Innovation Foundation (India)
NIFFR	National Institute for Freshwater Fisheries Research (Nigeria)
NIOMR	Nigerian Institute for Oceanography and Marine Research
NORAD	Norwegian Agency for Development Cooperation
NPK	Nitrogen, Phosphorus, Potassium

NPRS	National Poverty Reduction Strategy
NRCCF	National Research Center for Coldwater Fisheries
NSPFS	National Special Programme on Food Security
NUFASD	Nigeria Union of Fishermen and Seafood Dealers
NWFP	North West Frontier Province
NWP	North West Province (Sri Lanka)
OIE	World Animal Health Organisation (Office International des Epizooties)
OPIP	Provincial and National Fisheries Inspection Services (Cuba)
PADEK	Partnership for Development in Kampuchea
PAS	Philippine Aquaculture Society
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PCARRD	Philippine Council for Agricultural Resources Research and Development
PCR	polymerase chain reaction
PDA	Prawn Culture Project (Bangladesh)
PDAFF	Provincial Department of Agriculture, Forestry and Fisheries (Cambodia)
PFD	Provincial Fisheries Divisions (Cambodia)
PG	pituitary gland
PhD	Doctor of Philosophy
PHP	Philippine Peso
PKR	Pakistan Rupee
PL	Post-larvae
PMA	Plan for Modernization of Agriculture (Uganda)
PNVRA	National Agricultural Research and Extension Program
PPO	Private pond operator
PRA	participatory rural appraisal
PROSPER	<i>Procedure optimisee de selection individuelle par epreuves repetees</i>
QAAD	quarterly aquatic animal disease
QTL	quantitative trait loci
RA	Republic Act
RAPD	random amplified polymorphic DNA
RDRS	Rangpur Dinajpur Rural Services (Bangladesh)
RF	rice field
RFLP	restriction fragment length polymorphisms
RIA	Research Institute for Aquaculture
ROI	return on investment
ROS	Regional Outreach Stations (Philippines)
RRD	Red River Delta
RVDB	River Vallies Development Board
SAEP	Society of Aquaculture Engineers of the Philippines
SCA	Aquaculturists Association (Cuba)
SCALE	SAO Cambodia Aquaculture Low Expenditure
SEAFDEC-AQD	Southeast Asian Fisheries Development Center – Aquaculture Department
SEAP	Special Secretariat of Aquaculture and Fisheries
SEAPB	<i>Service d’Etudes et d’Appui aux Populations a la Base</i>
SEAP/PR	Special Secretariat of Aquaculture and Fisheries from the Presidency of the Republic of Brazil
SEC	southeast Cambodia

SEDPII	Second Five-Year Socio-economic Development Plan 2001–2005 (Cambodia)
SFD	States Fisheries Division (Nigeria)
SHG	Self-help Groups
SMC	San Miguel Corporation
SNPs	single nucleotide polymorphisms
SQIC	Seed Quality Inspection Centers
SPDC	Shell Petroleum Development Company
SPF	Specific pathogen free
SPR	Specific pathogen resistant
SPS Agreement	Sanitary and Phytosanitary Agreement of the World Trade Organization
SRS	self-recruiting species
SRT	Sex reversed tilapia
STREAM	Support to Regional Aquatic Resources Management
SUDA	Sustainable Aquaculture Development
SUFA	Support to Freshwater Aquaculture
SUMA	Support to Brackishwater and Marine Aquaculture
TCDC	Technical Cooperation Among Developing Nations
TCP	Technical Cooperation Programme
THB	Thailand Baht
Tk	Bangladesh Taka
TKFSPS	Toul Krasang Fish Seed Production Station (Cambodia)
TP	trap pond
TPCL	Tata Power Companies Limited
TSP	Triple super phosphate
TSV	Taura syndrome virus
UEM	University of Maringá in Paraná
UFAN	United Fisheries Association of Nigeria
UGX	Ugandan Shilling
UMATA	Unidades Municipales de Asistencia Técnica Agropecuaria
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UPMSI	University of the Philippines Marine Science Institute
UV	ultraviolet
VCDL	Vorion Chemicals and Distilleries Limited
VND	Viet Nam Dong
WB	World Bank
WBVA	Wild Bred Variety Amplifier
WFC	World Fish Center
WMD	White muscle disease
WRI	Water Research Institute
WSD	white spot disease
WSSV	white spot syndrome virus
WTD	white tail disease
WTO	World Trade Organization
WVCC	Wild Variety Collection Center
XAF	Cameroon CFA Franc BEAC
XSV	extra small virus
ZWD	Zimbabwe Dollar

Fish and other species

SCIENTIFIC NAME	COMMON NAME/LOCAL NAME
<i>Acipenser schrenckii</i>	Amur sturgeon
<i>Acrossocheilus hexagonolepis</i>	mahseer
<i>Aethiomastacembelus praensis</i>	spiny eel
<i>Amur pike</i>	pikes
<i>Anabas testudineus</i>	climbing perch, Thai koi
<i>Araipama gigas</i>	Pirarucu
<i>Argyrosomus regius</i>	meagre
<i>Arichthys aor</i>	singhari
<i>Aristichthys nobilis</i>	bighead carp
<i>Astronotus ocellatus</i>	apiairi
<i>Astyanax altiparanae</i>	lambari
<i>Bagarius bagarius</i>	catfish
<i>Barbodes gonionotus</i>	silver barb
<i>Barbonymus altus</i>	red-tail tinfoil barb
<i>Barbonymus gonionotus</i>	silver barb
<i>Barbus subinensis</i>	minnow, carp
<i>Brycon amazonicus</i>	matrinxa
<i>B. hildebrandi</i>	piraputanga yamú
<i>B. henni</i>	sabaleta
<i>B. orbignyanus</i>	piracanjuba
<i>B. siebenthalae</i>	yamú
<i>Botia birdi</i>	Birdi loach
<i>Carassius auratus</i>	ornamental goldfish
<i>Carassius auratus pengzeensis</i>	Pengze crucian carp
<i>C. carassius</i>	crucian carp
<i>Catla catla</i>	catla
<i>Chana obscura</i>	tilapia
<i>Channa asiatica</i>	Chinese snakehead
<i>C. gachua</i>	murrels
<i>C. marulius</i>	saul
<i>C. micropeltes</i>	giant snakehead
<i>C. punctatus</i>	murrels
<i>C. striata</i>	giant snakehead
<i>Chrysichthys nigrodigitatus</i>	tilapia
<i>C. walkeri</i>	Bagrid catfish
<i>Cichla ocellaris</i>	tucunare
<i>Cirrhinus cirrhosus</i>	mrigal
<i>C. molitorella</i>	mud carp
<i>Cirrhina mrigala</i>	mrigal
<i>Clarias x Heterobranchus</i>	hybrid catfish
<i>Clarias batrachus</i>	Asian catfish
<i>Clarias gariepinus</i>	African catfish
<i>Clarias macrocephalus</i>	walking catfish
<i>Clarias macrocephalus x C. gariepinus</i>	hybrid catfish
<i>Clarias gariepinus x C. batrachus</i>	hybrid catfish
<i>Clarias lazera</i>	sharptooth catfish

<i>Clarias</i> sp.	catfish
<i>Colisa lalia</i>	dwarf gourami
<i>C. macropomum</i>	tambaqui
<i>Colossoma macropomum</i>	black cachama
<i>Cristaria placata</i>	river shell, winkle shell
<i>Ctenopharyngodon idella</i>	grass carp, <i>Carpa herbivora</i>
<i>Cylocheilichthys enoplos</i>	cyprinid
<i>Cyprinus carpio</i>	common carp, <i>Carpa comun</i>
<i>Cyprinus carpio singuomensis</i>	common carp
<i>Cyprinus carpio</i> var. jian	Jian carp
<i>Cyprinus carpio</i> var. specularis	mirror carp
<i>Cyprinus carpio</i> var. wuyanensis	common carp
<i>Dicentrarchus labrax</i>	European seabass
<i>Erythroculter ilishaeformis</i>	topmouth culter
<i>Fenneropenaeus chinensis</i>	fleshy prawn, Chinese white shrimp.
<i>Fugu obscurus</i>	pufferfish
<i>Fugu xanthopterus</i>	pufferfish
<i>Gadusia chapra</i>	clupeid
<i>Glossogobius giurus</i>	goby
<i>Glyptothorax kashmirensis</i>	catfish
<i>G. reticulatum</i>	catfish
<i>Gymnacus niloticus</i>	tilapia
<i>Hemibagrus wyckioides</i>	<i>Hemibagrus</i> catfish
<i>Hemichromis elongates</i>	banded jewelfish
<i>Hemosorubim platyrhynchus</i>	juropoca
<i>Heterobranchus bidorsalis</i>	African clariid catfish
<i>H. longifilis</i>	Vundu catfish
<i>Heteropneustes fossilis</i>	Asian catfish, shing
<i>Heterotis niloticus</i>	kanga
<i>Hilsa ilisha</i>	clupeid
<i>Hoplis malabaricus</i>	trairao
<i>Hypophthalmichthys harmandi</i>	Vietnamese silver carp
<i>H. molitrix</i>	silver carp, <i>Carpa plateada</i>
<i>Hyriopsis cumingi</i>	triangle mussel
<i>H. schlegeri</i>	pearly mussel
<i>Ictalurus nebulosus</i>	bullhead brown catfish
<i>I. punctatus</i>	channel catfish
<i>Labeo bata</i>	Ilsha bata
<i>L. calbasu</i>	kalbaush
<i>L. chrysophekadion</i>	black sharkminnow
<i>L. dero</i>	carp
<i>L. fimbriatus</i>	carp
<i>L. gonia</i>	Kurio labeo
<i>Lates niloticus</i>	tilapia
<i>Labeo calbasu</i>	kalbaush
<i>L. rohita</i>	rohu, rui
<i>Leiarius marmoratus</i>	yaque
<i>Lepomis macrochirus</i>	bluegill
<i>L. amblyrhynchus</i>	chimbore
<i>L. elegantus</i>	piapara
<i>L. friderici</i>	piau
<i>L. macrocephalus</i>	piauvucu, piaucu
<i>L. obtusidens</i>	piava

<i>Leptobarbus hoevenii</i>	hoven's carp
<i>Liza ramada</i>	thin-lipped grey mullet
<i>Macrobrachium brimanicu m</i>	freshwater prawn
<i>M. malcolmsoni</i>	freshwater prawn
<i>M. rosenbergi</i>	freshwater prawn
<i>M. vollehonvenii</i>	freshwater shrimp
<i>Mastacembelus</i> spp.	mahseer
<i>Megalobrama amblycephala</i>	blunt snout bream
<i>Megalobrama terminalis</i>	black Amur bream
<i>Micropterus salmoides</i>	black bass, <i>Trucha americana</i>
<i>Misgurnus mizolepis</i>	Korean mud loach
<i>Morone chrysops</i> x <i>M. saxilis</i>	hybrid striped seabass
<i>Morulus chrysophekadion</i>	black shark
<i>Mugil cephalus</i>	mullet
<i>Mugil</i> sp.	mullet
<i>Mystus cavasius</i>	Gangetic mystus
<i>Mylopharyngodon piceus</i>	black carp
<i>Myxocyprinus</i>	Chinese high fin banded shark
<i>Notopterus chitala</i>	featherback
<i>N. notopterus</i>	Notopterus, featherback
<i>Ompok bimaculatus</i>	catfish
<i>O. pabda</i>	Pabda, butterfly catfish
<i>Oncorhynchus mykiss</i>	rainbow trout
<i>Ophiocephalus micropeltes</i>	snakehead
<i>Oreochromis aureus</i>	tilapia
<i>O. leucostictus</i>	mbiru
<i>O. macrochir</i>	tilapia
<i>O. mossambicus</i> x <i>O. niloticus</i>	red tilapia
<i>O. mortimeri</i>	tilapia
<i>O. niloticus</i>	tilapia, Nile tilapia, GIFT tilapia
<i>O. nilotics</i> x <i>O. aureus</i>	hybrid tilapia
<i>Osphronemus goramy</i>	giant gourami
<i>Osteobagrus aor</i>	catfish
<i>O. seenghala</i>	catfish
<i>Osteochilus melanopleura</i>	local name krom, cyprinid
<i>Oxyeleotris marmoratus</i>	sand goby
<i>Pangasianodon hypophthalmus</i>	pangasiid catfishes (river catfish, sutchi catfish)
<i>Pangasius conchophilu</i>	pangasiid catfishes
<i>P. larmaudiei</i>	pangasiid catfishes
<i>P. bocourti</i>	pangasiid catfishes
<i>Pangasius sutchi</i>	Thai pangas
<i>Patinopecten yessoensis</i>	Japanese scallop
<i>Parachanna obscura</i>	snakehead
<i>Piaractus brachypomus</i>	black cachama
<i>Piaractus mesopotamicus</i>	pacu
<i>P. brachypomus</i>	pirapitinga
<i>Pimelodus blochii</i>	nicuro
<i>P. grosscopfii</i>	capaz
<i>Plagiognathops microlepis</i>	Smallscale yellowfin
<i>Plecoglossus altivelis</i>	Japanese ayu
<i>Phractocephalus hemiliopterus</i>	pirarara
<i>Prochilodus lineatus</i>	curimbatá, curimba
<i>Prochylodus magdalenae</i>	bocachico

<i>Pseudoplatistoma fasiatum</i>	bagre rayado
<i>P. tigrinum</i>	bagre rayado
<i>Pseudoplatystoma</i> spp.	Pintado, surubim, cachara
<i>Puntius sarana</i>	Olive barb
<i>P. conchonius</i>	rosy barb
<i>Rita pevimentata</i>	catfish
<i>R. rita</i>	catfish
<i>Rana heckstheri</i>	frog
<i>Rhandia</i> spp.	jundiá
<i>Rhinomugil corsula</i>	Indian mullet
<i>Salminus brasiliensis</i>	dourado
<i>S. maxillosus</i>	dourado
<i>Salmo fario</i>	brown trout
<i>S. trutta</i>	brown trout
<i>Sarotherodon galilaeus</i>	tilapia
<i>S. melanopleura</i>	tilapia
<i>Schizothorax</i> spp.	carp
<i>Semaprochilodus</i> sp.	jaraqui
<i>Setipina phasa</i>	clupeid
<i>Silonia silondia</i>	catfish
<i>Sorobim lima</i>	jurupenses
<i>Sparus aurata</i>	gilthead seabream
<i>Spinibarbus sinensis</i>	barbodes
<i>Steatocranus irvinea</i>	bream or mango fish
<i>Synodontis arnoulti</i>	squeakers or upside-down catfishes
<i>S. macrophthalmus</i>	squeakers or upside-down catfishes
<i>S. velifer</i>	Eupterus
<i>Takifugu flavidus</i>	towny puffer
<i>Tenualosa ilisha</i>	Indian chad
<i>Tilapia aurea</i>	blue tilapia
<i>T. guineansis</i>	tilapia
<i>T. nilotica</i>	Nile tilapia
<i>T. rendali</i>	tilapia
<i>T. sparmanni</i>	tilapia
<i>T. zilli</i>	tilapia
<i>Tor khudree</i>	Deccan mahseer
<i>T. macrolepis</i>	Golden mahseer
<i>T. mosal</i>	mahseer
<i>T. mussulla</i>	mahseer
<i>T. nelli</i>	mahseer
<i>T. progenies</i>	mahseer
<i>T. putitora</i>	Putitor
<i>T. tor</i>	mahseer
<i>Trichogaster pectoralis</i>	snakeskin gourami
<i>Trionyx sinensis</i>	soft-shell turtle
<i>Valamugil seheli</i>	bluespot mullet
<i>Wallago attu</i>	catfish
<i>Xenocypris argentea</i>	yellowfin
<i>Xiphophorus helleri</i>	green swordtail

Annexes, boxes, figures, plates, tables

3.1 WORKING GROUP 1: KEY ISSUES CONCERNING SEED QUALITY, GENETICS, TECHNOLOGY AND CERTIFICATION

Table 3.1.1	Table of seed quality features and the issues that relate to them in terms of threat to the operation or opportunity to improve the product
Table 3.1.2	Possible scoring for quality features, ease of assessment of overall seed quality
Table 3.1.3	Seed quality features and the critical monitoring points at which they could be applied

3.2 WORKING GROUP 2: KEY ISSUES CONCERNING SEED NETWORKING, DISTRIBUTION, ENTREPRENEURSHIP (AND CERTIFICATION)

Table 3.2.1	Issues and concerns in aquaculture seed production and distribution
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4.0 ANNEXES

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Annex 4.2	List of participants
Annex 4.3	Welcome remarks of Prof Xu Pao, Director of the Freshwater Fisheries Research Center, Chinese Academy of Fishery Sciences
Annex 4.4	Welcome remarks of Mrs Wei Shaofeng, Bureau Director, Jiangsu Provincial Marine and Fishery Bureau

5.0 COUNTRY CASE STUDY TEMPLATE

6.1 FRESHWATER FISH SEED RESOURCES AND SUPPLY IN AFRICA: A REGIONAL SYNTHESIS

Figure 6.1.1	Main predators of catfish larvae
Figure 6.1.2	Comparison of growth among feral and captive populations of <i>Oreochromis niloticus</i> in Cameroon
Table 6.1.1	Authors of country case studies
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 Small GIFT strain Nile tilapia used for stocking ricefields. Fish seed traders have been important in moving broodfish between areas encouraging farmers to produce seed
 Plots used for seed production are often located close to the homestead. This picture shows preparation of the ditch or refuge, used for holding breeding fish and then for concentrating juveniles prior to harvest
 Children catch many of the fish used for home consumption used for home consumption derived from ricefield based fingerling production. The harvest is used for selling juveniles, re-stocking for further culture or eaten or sold for food fish. This flexibility is highly valued by farming households

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