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The future of mariculture: a regional approach for responsible development in the Asia-Pacific region

FAO/NACA Regional Workshop
7–11 March 2006
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Cover photo: Finfish cage mariculture in China (courtesy of Chen Jiaxin).

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The future of mariculture: a regional approach for responsible development in the Asia-Pacific region

FAO/NACA Regional Workshop
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Preparation of this document

This document contains the proceedings of the regional workshop entitled "*The Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region*" held from 7 to 11 March 2006 in Guangzhou, China, and organized by the Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO) and the Network of Aquaculture Centres in Asia-Pacific (NACA). It includes the workshop summary as well as all the papers presented. The papers provide up-to-date information on the status of mariculture in the Asia-Pacific region, major opportunities and constraints, and recommended actions for its future responsible development.

This publication is aimed at fishers, farmers, researchers, managers and policy-makers. It is hoped that it will assist international and regional development organizations and national governments.

The papers, submitted by the participants at the regional mariculture workshop, have been technically edited by FAO and NACA.

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Abstract

Aquaculture in the southeast Asian region has been growing steadily over the last few decades, requiring more space to accommodate it. The search for additional areas to expand the aquaculture industry as a whole and the identification of new farming species of commercial value to satisfy the growing local and export markets are pushing the sector in some countries to expand its activities in the sea, including further offshore where more space is available and where, to a lesser extent, competition is currently not so intense. During the latest session of the FAO Committee on Fisheries (COFI) and the Sub-Committee on Aquaculture (COFI-SCA), members requested that FAO look into issues related to the sustainable development of coastal aquaculture and in particular mariculture.

The FAO Fisheries and Aquaculture Department in collaboration with the Network of Aquaculture Centres in Asia-Pacific (NACA) organized the regional workshop entitled "*The Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region*" from 7 to 11 March 2006. The workshop, held in Guangzhou, China, was conducted in collaboration with the Bureau of Fisheries of the People's Republic of China and the Guangdong Ocean and Fisheries Administration.

Fifty-one participants from governments, business, non-governmental organizations (NGOs), universities and regional and international organizations from mariculture-producing countries around the Asia-Pacific region attended the workshop.

The workshop was convened in response to requests from FAO and NACA members to identify key trends and issues affecting mariculture growth in the Asia-Pacific region and to strengthen regional collaboration for future responsible development of mariculture. China's hosting of the workshop recognizes the status of China as the leading mariculture-producing country in the world and a major market for mariculture products from around the Asia-Pacific region.

The workshop was organized in complementary sessions. The first consisted of a series of presentations and discussions on country trends and thematic reviews on selected key issues. The second continued with three working groups focusing on important topics, namely: 1) Market, Demand and Trade; 2) Livelihoods, Producer Organizations, Technology Transfer and Communications; and 3) Mariculture Species and Systems. The third session comprised a "farmer dialogue" and a "trader and marketing dialogue". The farmer dialogue was conducted at a large mariculture farming area near Guangzhou, while the trader and marketing dialogue was conducted at the largest live-seafood market in Asia. These dialogues yielded valuable insights and recommendations from farmers and traders.

The final plenary session brought together the working group findings and identified opportunities for regional collaborative action. The workshop participants proposed the establishment of a regional "Asia-Pacific Mariculture Cooperation" initiative to support the development of sustainable mariculture in the Asia-Pacific region. The initiative will facilitate cooperation among the countries of the region by promoting responsible mariculture farming technologies, capacity-building, market access and effective transfer of knowledge. The platform for the initiative would be the "Asia-Pacific Marine Finfish Aquaculture Network", which is already promoting cooperation in marine fish farming around the region and has been widely seen as a successful programme. FAO and NACA were requested to facilitate and support the development of this new mariculture initiative.

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Participation of the experts at the workshop was possible through the assistance of Food and Agriculture Organization of the United Nations (FAO) as well as of a number of other regional and national bodies and institutions. The Secretariat of the Pacific Community (SPC), Pukyong National University (PKNU), INFOFISH, InterVet-Singapore, University College Science and Technology Malaysia (KUSTEM), the Marine Products Export Development Authority (MPEDA), the Southeast Asian Fisheries Development Center (SEAFDEC), SEAPlant, SINTEF, the Royal Swedish Academy of Sciences and the World Wildlife Fund (WWF-US) are acknowledged for their contributions. Thanks are also given to all the other institutions that permitted their experts to prepare for and attend the workshop.

Finally, the opportunity is taken to thank all the FAO and NACA staff members in Rome, Bangkok and Beijing who contributed in one way or another to the organization of the workshop.

The graphic layout of this publication was prepared by Koen Ivens.

Abbreviations and acronyms

ADB	Asian Development Bank
APMFAN	Asia-Pacific Marine Finfish Aquaculture Network
APRACA	Asia-Pacific Rural and Agricultural Credit Association
AR	Artificial Reefs
ARMM	Autonomous Region in Muslim Mindanao
ASEAN	Association of Southeast Asian Nations
ATIC	Agriculture Technology Information Centre
BDSP	Business Development Service Providers
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BFFDA	Brackish water Fish Farmer's Development Agency (India)
BIMP-EAGA	Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area
BKC	benzalkonium chloride
BMN	baculoviral mid-gut gland necrosis virus
BMP	Better Management Practice
CAA	Coastal Aquaculture Authority (India)
CBA	Capture-based aquaculture
CCRF	Code of Conduct for Responsible Fisheries
CFRDCs	Coastal Fisheries Research and Development Centers
CIBA	Central Institute of Brackishwater Aquaculture (India)
CIFRI	Central Inland Capture Fisheries Research Institute
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CMFRI	Central Marine Fisheries Research Institute (India)
CSMCRI	Central Salt and Marine Chemical Research Institute (India)
COC	Code of Conduct
CRZ	Coastal Regulatory Zone
CSR	corporate social responsibility
DANIDA	Danish International Development Agency
DFID	Department for International Development (United Kingdom)
DO	dissolved oxygen
DOF	Department of Fisheries
DGA	Directorate General of Aquaculture (Indonesia)
DWCRA	Development of Women and Children in Rural Area
EEZ	exclusive economic zone
EIA	environmental impact assessment
EIS	environmental impact statement

EAMAR	Ecosystem Approach to Mariculture
EMC	Executive Management Council
EMMP	Environmental Monitoring and Management Programme
EU	European Union
FAD	fish aggregation device
FAO	Food and Agriculture Organization of the United Nations
FCR	food conversion ratio
FDA	Food and Drug Administration
FMIRI	Fishery Machinery and Instrument Research Institute
FOB	freight on board
FRA	Fisheries Research Agency (Japan)
GAA	Global Aquaculture Alliance
GAP	Good Aquaculture Practice
GDP	gross domestic product
GIS	Geographic Information System
GSP	generalized scheme of tariff preferences
HACCP	Hazard Analysis and Critical Control Point
HDPE	high-density polyethylene
HPV	hepatopancreatic parvovirus
HRD	human resource development
HRV	hirame rhabdovirus
IAM	Institute of Marine Aquaculture (Malaysia)
IAS	Information Access Survey
ICAHR	Institute of Coastal Aquatic Health Research (Thailand)
ICAR	Indian Council of Agricultural Research
IFC-PENSA	International Finance Corporation-Program for Eastern Indonesia Small and Medium Enterprise Assistance
IFI	international finance institutions
IFPRI	International Food Policy Research Institute
IT	information technology
IVLP	Institution Village Linkage Programme
JICA	Japanese International Cooperation Agency
KCS	Knowledge Consuming System
KDS	Knowledge Disseminating System
KGS	Knowledge Generating System
KUSTEM	Kolej Universiti Sains dan Teknologi Malaysia
LFTV	Live Fish Transport Vessel
LGU	Local Government Unit
LHRH	Luteinizing Hormone-Releasing Hormone
LIFDCs	Low Income Food-Deficit Countries
MAC	Marine Aquarium Council

MBV	monodon baculovirus
MFPRC	Marine Finfish Production and Research Centre (Malaysia)
MFRD	Marine Fisheries Research Department (Singapore)
MFRDMD	Marine Fisheries Resource Development and Management Department (Malaysia)
MOMAF	Ministry of Maritime Affairs and Fisheries (Republic of Korea)
MoU	Memorandum of Understanding
MPA	marine protected area
MPEDA	Marine Products Export Development Authority (India)
MSC	Marine Stewardship Council
MSME	Micro, Small and Medium Enterprises
MTCP	Malaysia Technical Cooperation Programme
MTPDP	Medium-Term Philippine Development Plan
NABARD	National Bank for Agricultural Development (India)
NACA	Network of Aquaculture Centres in Asia-Pacific
NAFIQAVED	National Fisheries Quality Assurance and Veterinary Directorate (Viet Nam)
NAPFRE	National Prawn Fry Research and Production Centre (Malaysia)
NCAP	National Centre for Agricultural Economics and Policy Research (India)
NCSE	National Center for Stock Enhancement (Japan)
NFRDI	National Fisheries Research Development Institute (Republic of Korea)
NGO	non-governmental organization
NICA	National Institute of Coastal Aquaculture (Thailand)
NMFS	National Marine Fisheries Service (United States of America)
NORAD	Norwegian Agency for Cooperation and Development
NSSO	National Sample Survey Organization (India)
OIE	World Organization for Animal Health (formerly Office International des Épizooties)
PCR	polymerase chain reaction
PFO	Provincial Fisheries Officer
PGMA	President Gloria Macapagal Arroyo
PL	postlarvae
PSB	photosynthetic bacteria
PSP	paralytic shellfish poisoning
RCC	reinforced concrete cement
PCR	polymerase chain reaction
PKNU	Pukyong National University (Republic of Korea)
R&D	research and development
R,D&E	research, development and extension
RGCA	Rajiv Gandhi Centre for Aquaculture (India)

RRSEA	Reefs at Risk in Southeast Asia
SAUs	state agriculture universities
SCUBA	Self-Contained Underwater Breathing Apparatus
SEAFDEC	Southeast Asian Fisheries Development Center
SFH	Small Fishery Household
SHG(s)	self help group(s)
SIDS	Small Island Developing States
SMEs	Small and Medium Enterprises
SPC	Secretariat of the Pacific Community
SPF	specific pathogen free
SPLAM	Skim Pensijilan Ladang Akuakultur Malaysia - Farm Certification Scheme (Malaysian acronym)
SPS	sanitary and phytosanitary
SRC	semi-refined carrageenan
SUMA	Support to Marine and Brackishwater Aquaculture (of DANIDA)
TIUs	technical implementation units
TL	total length
ToT	transfer of technology
TSV	Tara syndrome virus
UNEP	United Nations Environment Programme
UNP	University of Northern Philippines
USFDA	United States Food and Drug Administration
UV	ultraviolet light
VAs	volunteer agencies
VHS	viral hemorrhagic septisemia
VNN	viral nervous necrosis
WB	World Bank
WSD	whitespot disease
WSSV	white spot syndrome virus
WWF	World Wildlife Fund
YAV	yellowtail ascites virus

Workshop summary

BACKGROUND AND WORKSHOP ORGANIZATION

The Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO) and the Network of Aquaculture Centres in Asia-Pacific (NACA) organized the workshop "*The Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region*" from 7 to 11 March 2006. The workshop was conducted in collaboration with the Ministry of Fisheries of the People's Republic of China and the Guangdong Ocean and Fisheries Administration.

The regional workshop, held in Guangzhou, China, was attended by 51 participants from governments, business, nongovernmental organizations (NGOs), universities and regional and international organizations from mariculture-producing countries around the Asia-Pacific region.

The workshop was convened in response to requests from FAO and NACA members to identify key trends and issues affecting mariculture growth in the Asia-Pacific region, and to strengthen regional collaboration for future responsible development of mariculture. China's hosting the workshop recognizes the status of China as the leading mariculture country in the world and a major market for mariculture products from around the Asia-Pacific region.

The workshop was organized in complementary sessions. The first sessions comprised presentations and discussions on country trends and thematic reviews on selected key issues. The second sessions continued with three working groups focusing on important topics, namely: 1) Market, Demand and Trade, 2) Livelihoods, Producer Organizations, Technology Transfer and Communications, and 3) Mariculture Species and Systems. The third sessions comprised a "farmer dialogue" and a "trader and marketing dialogue". The farmer dialogue was made at a large mariculture farming area near Guangzhou, while the trader and marketing dialogue was held at the largest live-seafood market in Asia. These dialogues yielded valuable insights and recommendations from farmers and traders.

The final plenary brought together the working group findings and prepared a framework for regional collaborative action. The workshop participants proposed the establishment of a regional "Asia-Pacific Mariculture Cooperation" initiative to support the development of sustainable mariculture in the Asia-Pacific region. The initiative would facilitate cooperation around the region by promoting responsible mariculture farming technologies, capacity building, market access and effective transfer of knowledge. The platform for the initiative would be the "Asia-Pacific Marine Finfish Aquaculture Network", which is promoting cooperation in marine fish farming around the region and has been widely seen as successful. FAO and NACA were requested to facilitate and support the development of this new mariculture initiative.

This summary provides the background to the workshop and main findings and conclusions. It is supplemented by further sections providing the thematic reviews commissioned for presentation at the workshop, country/regional reviews, special reviews prepared by participants and outcomes from the farmer and market dialogues. The workshop programme and participant list are given in Annexes 1 and 2, respectively.

WORKING GROUP FINDINGS

Markets, demand and trade

This Working Group discussion focused on maricultured seafood, i.e. products specifically farmed in the sea. It recognized that some lessons could be learned from the shrimp trade, but the group did not discuss shrimp. The factors affecting the demand for farmed seafood were identified as follows: (i) reliable supply, (ii) affordability, (iii) food safety; (iv) traceability and (v) consumer preferences.

Major issues

There is a growing demand in the region for seafood. Urbanization and the wealth of the urban populations are also generally increasing. There are different subsegments of the market – wholesale, domestic, restaurant, supermarket, processors and industry (for non-food use), each with specific demand trends and requirements.

There is a high diversity in fish species, and far less species diversity within the molluscan and seaweed commodities. Marketing chains are a critical factor, as the efficiency of the chain affects the ability to fulfill demands.

Small producers could find it difficult to meet the demands of consumers in terms of quality, reliability of supply, safety of the products and price. On the other hand, the high degree of diversity of species demanded by consumers gives opportunities to smaller or niche producers.

Increasing prices for wild fish and increasing quality of aquaculture products increases acceptability of cultured fish. The price differential between wild and cultured fish in China, Hong Kong Special Administration Region (SAR), for example, is decreasing and prices are getting closer for most species.

For live or fresh fish products, there is still a general preference for wild product over cultured product in the region. However, wild fish quality can be variable and aquaculture offers the potential for a more standardized (or even safer or superior quality) product. This group includes live species such as groupers.

Challenges

There are a number of challenges related to market demand and trade.

Technical challenges include:

- how to keep fish alive until the market;
- how to reduce transportation costs;
- how to make supply consistent/reliable;
- how to make the cultured product closer to the desired quality (comparable to wild-caught type, freshness, smell, fattiness);
- how to ensure the product meets quality requirements;
- how to ensure product safety; and
- how to set up the minimum food safety guideline for the world trade of marine aquaculture products.

Marketing challenges include:

- how to avoid flooding the market;
- how to distinguish between wild and cultured fish (labelling issues);
- how to expand the market;
- how to change consumer habits (i.e. how to shift consumers from live to frozen fish);
- how to get consumers to accept different species;
- how to ensure that farmers get a fair price; and
- how to communicate consumers' needs and preferences to producers.

For "*fresh or frozen mass-produced fish commodities*" there is already a demand for mass-produced fish from mariculture in nearshore and offshore cages. These include such species as milkfish, Asian seabass, cobia, seabream, yellowtail, flounder and turbot, which are now widely farmed. The larger operations have direct sales of fish that are not usually live. There is also a trend towards more convenient products in urban markets. However, prices of fresh and frozen fish will not increase greatly or may even decrease (supermarkets also tend to squeeze prices). If prices are not likely to increase, margins will have to come from improved efficiency. There is some scope to do this without compromising the quality of the product, raising the following points:

- how to get consumers to accept different product form (particularly frozen versus fresh);
- how to make cobia and milkfish more widely accepted in export markets;
- how to popularize Asian species in the European and United States of America markets (models similar to Vietnamese *basa*, tilapia, etc.);
- how to expand markets for milkfish (how to increase production), particularly processed (boneless/cooked);
- how to reduce production cost for Asian seabass fillets (price too low);.
- how to improve market diversity via processing or value adding of products;
- how to reduce production costs generally (increase survival, improve health etc.);
- how to get a higher degree of standardization of mass production to ensure acceptability of product in the international market (i.e. the salmon model) – this requires feed control, environmental monitoring, vaccination, no antibiotics, etc.; and
- how to get consumers to accept cultured fish over wild captured fish (quality of cultured product can be better than wild products; e.g. lower heavy metals or other residues).

For molluscs, the issues include:

- very different markets for groups: high-value (abalone, oyster, scallop), and low-value (cockles, clam, mussels);
- sanitary and phytosanitary (SPS) issues (particularly, monitoring of coastal waters for red tide/paralytic shellfish poisoning [PSP], etc., is critical);
- a lack of traceability systems – however, zoning of safe zones and area monitoring allows small-scale operations to work. (Note: urbanization and run off will increase in the short term, thus sites will be more constrained, and coastal land costs will increase, further limiting siting);
- a lack of regular monitoring systems (several countries have regular monitoring systems; others are trying to establish/get them up to standard; Thailand and Viet Nam can export to the European Union due to their monitoring systems);
- inspection by the United States Food and Drug Administration (USFDA) for oyster trade to the United States of America (safe/clean zones defined and inspected by FDA) is currently done for the Republic of Korea;
- importing countries sanction/inspect areas to allow product export; and
- processed products also allow smaller producers to access markets.

For seaweed, there is a need to distinguish between seaweed for food and seaweed for non-food uses. The edible market is saturated in the main markets (China, Japan, Republic of Korea) and thus the main growth area will be for non-food use. The issues include:

- how to enable seaweed producers to market more directly or to value-add (e.g. shortening of market chains; how to get groups of producers linked to more local production of semi-refined carrageenan);

- how to raise volume high enough to force some competition between buyers and prevent them from driving down price;
- how to cope with global price fluctuations;
- how to stabilize conditions so farmers produce more regularly; and
- how to standardize local refining techniques.

There are a number of niche species for mariculture with the following issues raised by the group:

- trade and aquaculture development for a number of species (e.g. sea cucumbers, sea horses) that are listed by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); and
- the development of hatchery techniques for marine ornamentals (90 percent captured) and ensure labeling and tracing of their products.

Exploring opportunities for derived products/extracts from mariculture

A wide range of derivatives from maricultured products exist but remain to be explored. There are already markets for these but the supply-demand connection has not been adequately developed. Improved refining techniques are required for local extraction. Considerable opportunities exist for diversifying production systems or developing/introducing methods for their extraction; however improved refining techniques are required for local extraction. These products include:

- nutraceuticals,
- feed additives,
- pigments,
- biopolymers,
- lipids,
- proteins,
- bio-active compounds, and
- microalgae for feeds (animal diets – *Spirulina*, *Dunaliella*, etc.).

Sharing of experiences on developing systems

Markets are by their nature competitive. This challenges us to find areas where we can realistically collaborate. In many cases cooperation is not attractive, as it might erode the market advantage of a country or a business. The most likely area for cooperation is in the area of standardization or harmonization to access markets outside the region or to facilitate intraregional trade.

Recommendations

The group identified a number of actions to address the following issues:

<u>Market intelligence and prospective market analysis</u>. There is a need for a clearer analysis of the structure of the emerging/projected demands. In particular, can the expected demand be disaggregated (i.e. how much is going to be for low-value, high-value, fresh, processed, from mariculture, from freshwater, etc.)? Is it possible to predict where these parts of the markets will be and in which countries?

Follow up actions: Analysis by INFOFISH for this workshop should be published as a forward view of mariculture. Specific country and commodity studies are required due to the very high diversity of products and markets at the national level. Generic analysis is not informative enough as to where true opportunities lie. Specifically, studies should identify where the demand will come from and what is the demand by socio-economic groups. A specific analysis should be conducted on mariculture trends, markets and regulations in China.

Facilitate closer cooperation/contact between producers and traders. Knowledge of who produces what and where is valuable, as the lack of knowledge of marketing and transportation channels limits opportunities for development of mariculture.

Follow up actions: Improve information systems between markets and producers. As a first step, more country contacts could be promoted by developing/sharing lists of producer groups/commodities.

Quality, safety and traceability. Harmonization will be key (with international standards and possibly inside the region). The Association of Southeast Asian Nations (ASEAN) has initiated work for processors, but this should be taken to the production level. Thailand is developing an information technology (IT) system for tracing shrimp from Code of Conduct (COC)/Good Aquaculture Practice (GAP) farms to processors, and several countries are also introducing various traceability and testing systems for quality assurance.

Follow up actions: Review of the COC/GAP/Better Management Practice (BMP) systems for the region should be conducted as a basis for development of a basic set of principles from which more specific commodity or system principles or standards could be developed. Harmonization of traceability/safety systems with the needs of importing countries should also be explored. An awareness raising/training course for safety and quality that links the various national initiatives at the commodity or sector level will also be necessary, as is assistance with training in detection/analysis and laboratory standardization.

Approved list/guide on therapeutants for mariculture, emerging issues for health and safety. The Network of Aquaculture Centres in Asia-Pacific Aquatic Animal Health Advisory Group should be approached to provide a specific veterinary guide to diseases and allowed therapeutants, supported by an agreed regional list and awareness materials.

Coastal monitoring systems (environmental monitoring, environmental quality, red tide). There are a number of mariculture zoning and environmental monitoring systems in the region, such as in Thailand (red tide, heavy metals, water quality), Viet Nam, the Republic of Korea (on-line system) and China, Hong Kong SAR.

Follow up actions: There should be a review of the coastal environmental monitoring systems of the region and workshop to agree on major factors and issues for mariculture zoning and environmental monitoring.

Certification and labeling, including ecolabeling. There are an increasing number of certification and labeling schemes emerging in the region.

Follow up actions: Pilot activity should be initiated on labeling according to emerging BMP for some specific pilot sites/commodities. A dialogue towards the emergence of specific commodity (or system-based) BMPs, including BMPs for cage mariculture and mollusc mariculture, should be started.

Regional standards. There is an absence of regional standards for major commodities.

Follow up actions: Regional standards should be developed for all major commodities. Expert consultation on one or two key species for setting out some baseline standards for production and quality should be initiated.

Addressing importing country concerns/demands and changing consumer awareness/preferences. Using the FAO/NACA/World Wildlife Fund/World Bank (WB)/United Nations Environment Programme (UNEP) Shrimp Consortium model, cooperation should be encouraged to start developing issues-based awareness and information for BMPs for the principle mariculture areas.

Follow up actions: A memorandum of understanding (MOU) should be developed between partners for a consortium model, with institutions to start developing issues-based awareness and information on principle mariculture areas – linked to BMP development for specific mariculture systems. Potential partners include: NACA, FAO, WWF, the Secretariat of the Pacific Community (SPC), the Southeast Asian Fisheries Development Center (SEAFDEC), UNEP, etc.

<u>Access to finance for small-scale aquaculture</u>. The Asia-Pacific Rural and Agricultural Credit Association (APRACA) has contact with national-level finance institutions and FAO, and APRACA have already done some work on financing of inland small-scale fisheries. With larger-scale mariculture aquaculture operations, there will be increasing interest in insurance (possibly for farmers who are organized and under BMP schemes).

Follow up actions: Initiate some financial analyses of risk versus income for aquaculture financing. Also explore whether this can be linked to implementation of BMPs. Engage with financial institutions (through dialogue with APRACA).

<u>Explore opportunities for derived products/extracts from mariculture</u>. A wide range of derivatives from maricultured products exist and remain to be explored. Markets for these already exist; however, the supply-demand connection has not been adequately developed. Considerable opportunities exist for diversifying production systems or developing/introducing methods for their extraction. These include:

- nutraceuticals,
- feed additives,
- pigments,
- biopolymers,
- lipids,
- proteins,
- bio-active compounds, and
- improved refining.

Follow up actions: Link to agricultural research institutions that are developing these products and their applications (link this to the supply end). Identify what they are looking for and determine where the raw products are and (possibly) primary processing could be done. Potential partners include NACA, SEAPLANT.NET, FAO, Australian Centre for International Agricultural Research (ACIAR) and others.

Livelihoods, producer organizations, technology transfer and communications

Major issues

Producer organizations and alliance networks are essential to the efficient development of business functions and industry representation functions for the mariculture sector of Asian economies. Producer organizations and alliance networks can prosper if – and only if – the following elements are available, accessible and effectively utilized:

- appropriate local, national and regional plans, including legal parameters that effect the industry;
- fair markets that include awareness of culture practices that relate to product quality and food safety and link effectively with market requirements;
- finance and insurance on equitable terms;
- knowledge, information, tools and skills relevant to appropriate technology,

markets, business management practices, environmental considerations and social impacts; and
- essential infrastructure, goods and services, including communication and logistical links.

Challenges

Organize producers, support alliances and build networks that will:
- facilitate the formation and operation of producer organizations through effective networking;
- facilitate the development of organizational initiatives that increase the market power of farmers, create a self-sustaining mechanism for the rapid dissemination of technology, stimulate experience sharing, foster implementation of better management practices and increase the strength of producer enterprises in negotiations with suppliers of inputs, buyers and financial service providers;
- establish networked knowledge and information centers with one-stop shops that provide advice on business planning, finance and compliance issues; and
- foster good social responsibility by industry stakeholders.

Further strengthen national and regional coordination in mariculture policy and planning, by:
- identifying priorities, constraints and opportunities for regional collaboration;
- integrating mariculture into overall coastal zone management and planning processes;
- facilitating the engagement of producers in mariculture policy development processes; and
- formalizing mariculture operations as legitimate users of coastal areas and resources (zoning and licensing).

Link to fair markets by:
- engaging regional institutions in facilitating market access;
- developing awareness concerning culture practices (including technology, product quality and food safety, linked with market access requirements);
- developing value-chain transparency through dissemination of market-related knowledge, information, tools and solutions;
- facilitating development of specific value chains from source to market;
- establishing and promulgating industry-standard quality protocols and procedures that are practical for producers to use; and
- tieing in regional facilities with the capacity to provide testing and technical support for verification and certification processes that support marketing.

Link to fair finance and insurance by:
- facilitating business development service providers (BDSP) that serve as interfaces between banks and producers;
- facilitating risk reduction measures;
- providing training in better farm and business management practices;
- assisting in implementation of standardized financial procedures;
- providing advice on the organization and management of credit unions and other self-financing arrangements;
- facilitating access to low-cost sources of credit through producer-based credit unions and revolving funds that encourage use of better management practices by members; and
- assisting banks to develop financial products that are appropriate for small and medium-scale producers.

Link to knowledge, information, tools and skills by:
- identifying and mobilizing regional institutions that can support development of effective “solution providers” to provide specialized technical and business

functions to mariculture value chains;
- developing a directory and a network of mariculture training providers;
- developing or translating appropriate syllabus and technical training materials in languages relevant to the region;
- promoting education and training in mariculture, livelihoods building and communication skills for farmers, extension workers and trainers; and
- engaging producers in the cycle of innovation and knowledge development.

Link to essential infrastructure, goods and services by:
- promoting the development of and ensuring access to essential infrastructure and services (e.g. moorings within designated mariculture zones);
- building efficient networks linking to essential farm inputs such as quality feed and seed, health advice, equipment supplies, market information and finance; and
- providing rapid access to technical services and information such as health management and environmental forecasting.

Recommendations

Value chain development. Select a few value chains that are of general regional significance and facilitate their development. Possibilities suggested for consideration include cage culture of tropical finfish for live markets, seaplants for specialty ingredient and agricultural uses, and bivalves for general nutritional purposes.

Identify and mobilize regional institutions that can support development of effective "solution providers". These can provide: business development advice and assistance; delivery of technical and business training; diagnostic, testing and treatment services; and linkages to the essentials of enterprise management and operation.

Geographic Information System (GIS). Mobilize regional institutions in development of a comprehensive mariculture-oriented geographic information system (GIS) for coastal regions. This can provide information that is of crucial importance to integrating mariculture into coastal zone management programmes, guidance as to seasonal management of mariculture operations, and a platform for the delivery of technical and market information.

Human resource development. Place special emphasis on institutional collaboration in human resource development. Suggested measures include: facilitating regional cooperation in development of education and training materials in the key languages of mariculturists in the region, developing networked technology transfer initiatives, and collaboration on the delivery of effective education to the locations where mariculture is practiced.

Regional cooperation. Coordinate participation of regional institutions in promoting infrastructure development and financial facilities that support the mariculture industry by encouraging private-sector initiatives (e.g. in providing finance); promoting institutional networking, both in-country and regionally; convincing institutions such as the international finance institutions (IFI) to fund infrastructure projects that support mariculture; and facilitating means by which mariculture organizations and stakeholders can be made aware of infrastructure and financing opportunities.

Mariculture species and systems

Major issues

Seedstock supply – Major issues include:

- availability (farmers have difficulty obtaining seedstock of the species that they would like to raise; for example, seedstock of lower-value groupers are available, but there is limited supply of the higher-value species desired by farmers;
- more information is needed on target species (e.g. growth rates) to allow farmers to make informed choices);
- price (cheaper seedstock would help reduce production cost);
- larval rearing technology (potential application of extensive larval rearing to improve cost-efficiency of production);
- quality (quality of seedstock is variable, and there are high levels of deformity in seedstock from some hatcheries; development of specific-pathogen-free (SPF) certification for seedstock is urgent);
- genetic management (source, quality and management of the broodstock, and the need for and the impacts of domestication of hatchery broodstock);
- over-production (there is overproduction of certain species, e.g. high production of green grouper has led to lower price);
- social issues (e.g. what are the benefits from as well as disadvantages of small, medium and large-scale hatcheries?);
- research and development in hatchery production (species, efficiency) (funding of research and implementation of outcomes);
- use of recirculation systems to improve biosecurity (improved water treatment technologies);
- high mortality in the nursery phase due to cannibalism, etc.; and
- layer of farmers/suppliers/middlemen in the supply chain and impacts on price.

Feeds – Major issues include:

- aquaculture feed in the Asia-Pacific region is largely dependent on "trash" fish;
- cost of feeds is important for farmers to reduce production costs;
- pellet diets are not available for some cultured species (the diversity of species produced in the Asia-Pacific region acts as a constraint in that different feeds need to be developed for different species or species groups; in addition, specialized feeds for different species or species groups may only be produced in relatively small quantities, precluding feed companies from utilizing economies of scale and resulting in a relatively expensive diet);
- farmers are often reluctant to adopt pellet feeds for a variety of reasons (farmers interviewed at Nan'ao Bay said they had heard that the use of pellet feeds resulted in lower-quality fish, for which the farmer received lower prices; consequently, they were reluctant to adopt pellet diets);.
- it may be necessary to implement incentives or disincentives to facilitate pellet feed adoption by farmers; and
- the impacts on product quality of pellet feeds are not well documented.

Environmental impacts – Major issues include:

- there is a need for integrated coastal zone management, including zoning for areas selected for mariculture production; and
- there is a general lack of knowledge of environmental impacts, particularly the impacts of aquaculture on the environment (there is a better appreciation of the impacts of the environment on mariculture production, for example, the impact of red tides on mortality).

Health – Major issues include:

- in many areas, there is a lack of diagnostic support for mariculture (consequently, farmers rely on their own experience or anecdotal information to diagnose and treat disease problems);
- farmers may not appreciate environment–disease interactions, so that they may not realize that negative environmental impacts affect their production;
- there is a need for specific pathogen free (SPF) certification schemes; and
- the impacts of transboundary movements and introductions need to be addressed.

Chemicals – Major issues include:

- the widespread use of unregistered or inappropriate chemicals to treat disease, which has environmental impacts and food safety implications;
- the possibility that different regulation levels for exported and domestic products exist;
- the need to harmonize chemical regulations (e.g. for chemical registration);
- the need for better education of farmers and extension agents on chemicals, such as types and dosages; and
- the need to tackle chemical-related problems on a farming-area basis because residues affect a whole area and farm clusters.

Implementation – Major issues include:

- the need for guidelines (BMPs as well as regulations);
- the need to develop incentives or disincentives (e.g. market access); and
- the need for certification of extension workers and fish health providers.

Production technologies – Major issues include:

- current production technologies (cage design, etc.) restrict mariculture to largely inshore areas (improved technologies (cages, moorings) will be necessary to move into offshore waters);
- there is a need to continue to support the development of small-scale farms with appropriate infrastructure and materials;
- much mariculture in the Asia-Pacific region is undertaken in typhoon-prone areas (production systems need to take into account the impacts of typhoons and other severe environmental conditions);
- mariculture development will need focus on reducing production costs to remain profitable in the face of increasing production (increased mechanization of farming, particularly large-scale farming, is likely to be necessary);
- better knowledge of site selection issues is required;
- environmental impacts and their assessment are becoming increasingly relevant in terms of public perception of aquaculture and as a source of local self-pollution;
- social aspects of mariculture are poorly known; and
- for capture-based aquaculture, that better knowledge of the seed resources and the impacts of their harvest are needed.

Better management practices – Major issues include:

Siting of mariculture:

- clear definitions are needed;
- carrying capacities of coastal tropical environments are not well known;
- assessment of carrying capacities and impact is system and/or scale- dependent;
- a guide for siting is needed; and
- the applicability of temperate models (salmonid models) to mariculture in tropical regions needs to be determined.

Gaps in licensing, policy and implementation including:

- basic guidelines and recommendations for site selection and zoning by technical experts are needed;
- technology (computing power) should be used;
- GIS for aquaculture coastal zoning is needed;
- an information hub to centralize information is required;
- environmental monitoring is needed;
- an integrated aquaculture approach (tackling issues at a larger scale, such as a whole bay) is needed; and
- carrying capacities (depending on species and production system) should be determined.

Opportunities and constraints to mariculture development

<u>Opportunities</u> – These include:

- increasing affluence in Asia is driving expanding markets for aquatic products (e.g. in China, more people are eating out in restaurants; live marine finfish, previously regarded as a luxury product, are now accessible to many Chinese);
- an ecosystem approach to mariculture development would enhance its long-term sustainability;
- opportunities for developing information services and networking will support this rapidly growing sector;
- many of the markets (e.g. in China) are located inland and far from the production sites; there is a need to develop more cost-effective transport systems to deliver product to these markets;
- development of sustainable mariculture can reduce the reliance on capture fisheries, easing pressure on over-exploited fisheries;
- certification and traceability programmes will benefit producers by increasing consumer confidence in the quality of the end product (however, concerns remain over the social equity of implementation of these schemes, as large commercial aquaculture concerns are more likely to be able to implement them, while small-scale farmers may find compliance difficult or costly, and thus be placed at a disadvantage); and
- mariculture in Asia-Pacific is notable for the high diversity of production as compared with aquaculture in Europe or North America (this provides opportunities for farmers to switch between commodities in response to factors such as price and risk; however, it also dilutes the research and development effort and results in a diversity of products that may not reach adequate economies of scale, for example, different marine finfish species require different grow-out diets and there can be no generic “marine finfish” diet).

<u>Constraints</u> – These include:

- intense competition in what is effectively a global market for seafood products;
- in some Asian countries, aquaculture is less attractive to young people as a career choice than alternatives (a “drift” of young people from the rural areas to the cities would reduce labour available for aquaculture);
- market chains in many countries are poorly developed, which decreases the profitability of mariculture enterprises;
- environmental degradation leads to less efficient production because of water quality-induced stress and increased prevalence of disease; and
- mariculture in the Asia-Pacific region still relies mainly on “trash” fish as a feed source.

Better management requirements

A cross-cutting need with regard to improved management of mariculture in the Asia-Pacific region is strategic planning for aquaculture production, including market demands and forecasting. More specific requirements for better management are noted below.

Seed stock supply:

- research, technical support and training for hatchery and nursery development; and
- and implementation of certification schemes based on BMPs to provide assured quality seed stock.

Feeds:

- availability of pellet feeds for specific aquaculture commodities (specific feeds will need to be formulated for species or groups of species); and
- incentives to use pellet feeds and disincentives to the use of trash fish are necessary to facilitate adoption of pellet feeds by farmers.

Environmental impacts:

- technologies (such as GIS) and databases to support coastal zoning and site selection;
- implementation of environmental monitoring systems;
- investigation of potential for transferring models and monitoring systems from temperate mariculture to tropical systems; and
- research in integrated mariculture to alleviate nutrient impacts in coastal and marine ecosystems.

Disease:

- improved diagnostic support;
- improved information and education for farmers; and
- legislation and enforcement of animal health issues.

Chemicals:

- responsible use of chemicals and therapeutics, incorporating incentives (education, technical support) and disincentives (monitoring, market access restrictions).

Production technologies:

- engineering to support offshore mariculture (however, many offshore areas in Asia are relatively shallow and thus inappropriate for adoption of deep-water systems being developed in Europe and North America);
- research, technical support and training in cage and other production systems design and management; and
- adoption of recirculation technology (in Asia, this has best application in hatchery and nursery facilities to support improved biosecurity).

Future cooperation

The Working Group discussed the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN) as a model for the proposed Asia-Pacific Mariculture Cooperation. APMFAN uses the following mechanisms to promote coordination and cooperation:

- Website (www.enaca.org/marinefish);
- electronic publications (e-mail – more than 900 subscribers);
- print publications;
- training courses;

- regional technical workshops;
- technical advice; and
- development of BMPs.

Cooperation objectives

Proposed objectives of the proposed Asia-Pacific Mariculture Cooperation include:
- support and develop sustainable growth of the mariculture industry in the Asia-Pacific region;
- promote the production of quality products to consumers addressing human health issues;
- intensify regional cooperation and promote knowledge transfer; and
- ensure that mariculture development contributes to sustainable livelihoods in coastal communities.

Mollusc aquaculture cooperation

The Working Group proposed the development of a mollusc aquaculture network along the lines of the marine finfish network coordinated by NACA. This network could incorporate other invertebrates such as sea cucumbers.

Work packages

The Working Group developed concept proposals for work packages to address the issues raised during the workshop.

Short-term work packages

Development of low-cost cages. Cooperation on low-cost cage technology could be undertaken by linking existing projects in Viet Nam and Philippines. Aspects of the work would include economic evaluation and design aspects (engineering). There was general interest in this topic from the countries represented in the Working Group, but particularly from the Islamic Republic of Iran and the Pacific Islands region.

Low technology hatchery systems for bivalves. This proposal is to adopt or adapt low-technology/high-volume hatchery technology for bivalves as is being done in Hainan (China). Countries where this technology has potential application include Thailand, the Philippines and the Pacific Islands. This technology adoption was also requested (through FAO) for the Democratic People's Republic of Korea.

Live feeds. This proposal is to improve the production (culture densities, reliability) of live feeds such as micro-algae, rotifers and copepods. It was noted that copepod culture is particularly important for marine finfish larval rearing, including cobia culture. Specific aspects that this project would address are:
- supply of axenic starter cultures, possibly from a centralized repository;
- enhanced self-reliance (extension of isolation and culture techniques to allow use of locally isolated organisms); and
- increasing culture density to improve cost-effectiveness of hatcheries.

Aquatic animal health. Specifically, this proposal is to develop and implement a training programme for extension staff to become "para-vets" to support improved aquatic animal health in the region. Staff would be trained to lower than veterinary standards, but would be provided a higher level of training than extension staff. Some support material already exists (e.g. NACA/FAO aquatic animal health guidelines). The project would be strongly linked to BMP projects.

Longline culture of bivalves. This proposal is to extend the existing large-scale longline culture techniques for bivalve culture to countries not currently practicing these techniques. Potential source countries are China, New Zealand, the Republic of Korea and Japan.

Recirculation technology. There is significant interest in recirculation technology among countries represented at the workshop. The most obvious application of recirculation technology in mariculture in the Asia-Pacific region is to support improved biosecurity in hatcheries and nurseries.

Seaweed diseases. The Working Group felt that collaboration with ongoing research in China on seaweed diseases would benefit other countries.

<u>Longer-term work packages</u>

Vaccine development. Efforts to develop vaccines for finfish should be linked. There is ongoing research and development in Viet Nam and Taiwan Province of China, among others. Opportunities for strong linkages with the private sector exist.

Ecosystem approach to aquaculture. The major overall objective of this project is to develop an ecosystem approach to aquaculture management involving all stakeholders. The ecosystem approach includes ecological, social and economic aspects as the three legs for sustainable aquaculture, thus assuring farmers their immediate and future livelihood and business.

Specific objectives would be to:

- collate information needed to develop an Ecosystem Approach to Mariculture (EAMAR), including:
    1. output: general minimal information needed for the implementation of EAMAR (general information on carrying capacity);
    2. activities: Workshops to define and collect minimal scientific, social and economic information needed for EAMAR; and
    3. indicator: to be developed.
- develop and implement coastal management and zoning plans based on EAMAR, including:
    1. output: aquaculture zone mapping for some or all countries;
    2. activities:
        i. GIS workshop including all stakeholders,
        ii. how to implement realistic and durable Environmental Impact Assessments (EIAs); and
        iii. polyculture, integrated aquaculture to reduce nutrient impacts.
    3. indicators: implementation of GIS-EAMAR zoning in some countries.
- training on BMPs and EAMAR for cage mariculture; and
- integrated monitoring of environmental conditions to support adaptive management, reduce environmental impacts and prevent the occurrence of environmental conditions that trigger such adverse phenomena as red tides.

Genetic improvement. Research on genetic improvement of freshwater species (e.g. tilapia) has provided substantial benefits to farmers. There are opportunities to undertake similar projects with marine finfish. There are plans to undertake selective breeding work with cobia in Viet Nam (funded by the Government of Viet Nam and Norway).

Triploid molluscs. Investigate the potential for wider adoption of triploidy for mollusc production.

Integrated mariculture. Integrated mariculture can reduce environmental impacts of aquaculture requiring feed inputs.

FINAL DISCUSSION AND WAY FORWARD

The final session of the workshop discussed the overall workshop findings and made recommendations for follow-up actions.

The country representatives and mariculture experts were in agreement as to the need for a regional mariculture programme, based on the findings of the workshop. Various participants made interventions to support strengthening of regional cooperation in mariculture. A summary of these interventions, including offers of assistance, is provided in Annex 3.

The participants recommended that NACA and FAO develop the regional mariculture programme to address the needs and recommendations identified above. In particular, NACA was requested to prepare and integrate the programme into its regional intergovernmental work programme and FAO was requested to provide facilitatory assistance to initiate the programme.

Farmer and trader dialogues

DIALOGUE WITH FARMERS

The workshop participants visited Nanhu Village, Gunagzhou, People's Republic of China on 9 March 2006 to view aquaculture facilities, discuss with marine fish farmers and better understand the status and issues associated with marine fish-farm development in the village. The intention was to ensure that the regional programme development was informed by the concerns of farmers. The following reports the main points arising during the dialogue:

- Eight experienced farmers from Nan Hu Village met with the workshop participants. Among them was one who has been a cage operator for over 20 years.
- Most of the present cage culturists were fishers. Cage culture was introduced to the area in the early 1980s. During the period 1983–1986, the price of finfish, especially seabream and groupers, was very high and farming was profitable. By the late 1980s, farmers began facing some difficulties due to increases in the price of feed and seed, outbreaks of disease and more people entering cage culture. During 1998–1999, they suffered mass mortalities from red tides. Since then the number of farmers has decreased.
- Nan Hu Village used to have 150 households, of which 90 percent were engaged in cage culture. Currently, the number of households has gone down to 100, with only three practicing cage culture. Most of the village people who stopped cage farming went back to fishing. Therefore, most of the cages situated inside the bay are empty and those that are operating are being run by people who have moved in from other areas of China. These newcomers are mostly using the cages as holding facilities for the trading of live fish from wild fisheries.
- The cage culture operations in the village are small scale and family based and devoted to the culture of high-value species. Feed is trash fish. Some farmers tried pellet feed but they claimed that the formulated feed affected the appearance and taste of the fish and so abandoned its use.
- The market-size fish are delivered to Shenzhen, China, Hong Kong SAR by boat and to Guangzhou by truck. On average they are receiving US$4–5/kg for green grouper. Among the various middlemen, China, Hong Kong SAR buyers usually offer the highest price. There used to be a high demand for green grouper of the

size 1.5 kg but nowadays smaller size fish are more in demand. The farmers think there has been a change in the consumer patterns; a smaller fish is more suitable for a family of two or three people.

- Even though they are located close to major fish markets, the generally low efficiency of farm operations is making the farming business difficult. Species in the markets are diversified and prices of local species are going down by as much as 50 percent for some species even as the cost of production remains the same or increases (annual costs of seed and feed for a small farm are 10 000 and 20 000–30 000 Yuan, respectively). Currently hatchery-reared seed are available for seabream, kingfish and green grouper, but there is still a shortage of seed for high-value grouper species.

- Environmental concerns include oil spills and leakages and other water pollution. They attribute the increasing pollution to the increased number of people who have settled in the village, many of whose homes are without proper sewage disposal and with no municipal sewage treatment system in place. They think this has increased the frequency of red tides. One farmer commented that waste feeds from farms are also causing pollution in the bay. The transparency of the water was 5–10 m in the early 1980s but is now less than a few meters. As well as the increasing turbidity, the mean temperatures are higher and the maximum water temperature exceeds 31 °C.

- There is no formal farming group, but many of the farmers are extended family members, relatives and friends. Because of the change in the economic situation, and with the family being the smallest unit, farmers feel it is difficult to organize a farmer association, which would have been useful for price negotiations.

- There is no conflict between cage farmers and other water resource users such as fishers and tourist operators because they are mostly members of extended families, relatives and friends, and they respect their activities as a whole community.

- In 2002 an ocean and coastal area management regulation was put in place. The regulation includes a zoning plan for the coastline (including Nan Hai Bay). Previously, aquaculture activities were controlled by the village, but under this regulation the local government assumed control of administration and issuance of licences. Under the government regulations only registration is required and there is no strict restriction about the zoning, i.e. siting of farms in the bay. There is an also an environmental regulation and policy in place, but one farmer said he saw no impact on changes in practices or on catches.

- In response to disease occurrence such as gill rot and infections that usually cause mortalities, the workers at the local fisheries institute and the extension office visit the area and advise farmers on control measures, including what chemicals to apply and how to reduce the future risk of disease. There were no regulations on the use of chemicals until recently. The drugs were mixed with the feed or applied through a freshwater bath.

- Another service provided by the authorities is a regular weather bulletin and typhoon warnings.

- Some of the farmers have changed to scallop farming, but they claim that scallop farms are more labour intensive and difficult for the small-scale family to operate. People in the village are aware of offshore-type cages but do not have the capital and experience for such a system. Because cage culture is seen as a high-risk business, the farmers cannot secure bank loans. The younger generation has little interest in fish farming because they think that the big companies with industrial-scale operations will dominate the sector.

- **Private industry: Xulian Group.** A large-scale aquaculture company operates in the area. The company is planning to install submerged cages in deeper areas to minimize the impacts of disease and other risks such as typhoon. They are expecting that better survival and higher quality will result from growing the fish in cleaner water. The company has gone on a study tour to Norway and Australia to learn the technology and the management of industrial-scale farming.

- The challenges that they may foresee include the costs of intensification of the operation and for machinery (net cleaner, harvest, etc.) and operational difficulties for treatment of disease in a larger scale. Their main concern is how to improve the cost effectiveness of the operations. However, the market in Shenzhen has a huge potential and there are seven million people in China, Hong Kong SAR, which receives 90 percent of its fish supply from overseas. They think that developing the marine culture industry in China will reduce China and China, Hong Kong SAR's reliance on overseas supply. This is the reason the company's farm has been set up in Daokon Bay, which is close to China, Hong Kong SAR. They plan to produce and trade, acting as brokers for imports. The company sees further opportunities for the industry to grow in this area. The younger generation, while no longer interested in farming, could be employed by industrial-scale operations. In addition, the area has potential as a tourist destination, its attractions including the possibility of enjoying good quality low-priced seafood.

DIALOGUE WITH TRADERS

The workshop participants visited Guangzhou Huangsha Seafood Market (China) on 10 March 2006 to view the market and its facilities, discuss with traders and managers and better understand the status and issues associated with mariculture marketing in Guangzhou. The intention was to ensure that the regional programme development was informed by the concerns of farmers. The following reports the main points arising during the dialogue:

- In 1995, the Ministry of Agriculture designated three major fish wholesale markets as key markets for China – Dalian (north), Shanghai (central) and Guangzhou (south).

- The Guangzhou Market was established in 1994, starting as the Guangzhou Fish Wholesale Market but is now in transition to become the Guangzhou Aquatic Products Central Wholesale Market. The current expansion has completed phase one of three phases. Originally occupying 2.6 ha, it has expanded to over 5 ha: the building area is more than 190 000 m^2. The market has a centralized system of seawater supply (filtered and chilled). The number of traders is about 300 (250 renting the existing space and 50 from the joint venture company that is funding the expansion). There is a fee for traders covering space rental that includes water supply, utilities, etc.

- The market is jointly owned and operated by the Municipal Port Authority and Guangzhou Municipal Fish Product Marketing Company. The market is now basically a fish wholesale market but the new market will have more functions. The ground and second floors are for trading of live aquatic products, the third floor for dried and processed products and the fourth floor will be rented to restaurant operators. A hotel is planned to be built as part of the effort to attract more tourists.

- Products from the market reach other markets and cities in the Pearl River delta as well as other cities throughout the country. The sources of the products are China and 20 other countries and territories. Daily trading volume is now about 500 tonnes and annual trading volume is about 180 000–190 000 tonnes with a total value of around 6–7 billion Yuan (close to US$1 billion).

- Most of the traded products are live but plans are to increase the volume of freshly chilled and frozen products. Compared with other markets in China, the Guangzhou market has the longest list of traded species: over 200 species traded. The market employs its own staff but also has support from the municipality, i.e. police, traffic wardens, trash collection and disposal, etc.

- The market has a functional system for quality inspection. According to government regulation, a system has been set up for testing and recording, which allows tracing products back to suppliers and location. Random sampling is conducted. Testing and monitoring covers live seafood for antibiotics and drugs used in transportation. Certain reef species are tested for ciguatera. The market has recently warned the traders on the sale of Napoleon wrasse after the species was listed in CITES. The traders think a law will be issued banning its sale. Young live Napoleon wrasses fetch the highest price, followed by the humpback or mouse grouper (*Cromileptes altivelis*).

- The market also has controls that limit entry of suppliers to the market. In order to be able to trade products to this market, the producers must be certified to allow them to supply.

- Most of the traders do not import directly but buy from importers, usually based in China, Hong Kong SAR. A lot of the product is transshipped though China, Hong Kong SAR. There are different types of operations; some traders are producers who sell their own product and also sell to other traders, others are merely traders. Marketing tools used by the wholesalers to attract customers are usually offers of preferential prices for regular customers (mostly big seafood restaurants with whom they have long-standing relationships). Adding new species to the list also attracts new customers. An example is the recent addition of South African abalone and a species of shrimp. The market is being promoted as a “market”. There is no specific promotion of individuals or individual products. For products from China, there are direct supply agreements and direct contracts to provide the products on a case by case basis. Live seafood imported through China, Hong Kong SAR is under a long-term contract with the China, Hong Kong SAR traders, who are usually relatives.

- The prices are generally constant but are sensitive to supply in the market so that availability of some species will strongly affect price. Of the products on sale, about 51 percent are freshwater and the rest are marine. Of the marine species, about 10 percent by volume is imported. One percent of this is directly imported. Countries that are imported from directly are Australia, Norway, Canada, Philippines, Malaysia, Thailand and Viet Nam. Generally if there is a direct flight, imports are directly shipped to Guangzhou, otherwise the products enter via China, Hong Kong SAR. Most of the imported products are traded through China, Hong Kong SAR, but the traders said they would prefer to deal directly with the exporting countries to shorten the market chain and reduce the transaction costs. A direct link might also increase the volume that is traded.

- The future outlook, based on the previous trends is that the split between marine and freshwater is likely to stay the same. It does appear that cultured species are increasing and wild captured species are decreasing. There is, however, a nationwide preference for wild fish (seen as higher prices). Most of the imported species are wild captured, very few are from aquaculture.

- There are slight changes for some of the traded species. Lobster volumes are decreasing. The traders are looking for new species to add to their lists, but there has been relatively little development of new species. The trend is that more people are able to afford live fish, as seen from the increase in traded volume. This increase is made possible by their ability to market their products into other regions of China, not just Guangzhou. Improving transportation and ability to maintain live fish have spread the live fish market widely. The live fish trading volume will probably stay the same but increases are foreseen in the trading of chilled or frozen products. Import tariffs are being lowered.

- Imported molluscs have to compete with the products from Dalian Province in northern China. Unless their price is competitive, imports would have difficulty entering the Chinese market. Some mollusc species that used to be expensive are getting cheaper (e.g. *Babylonia* snail) due to imports.

- From aquaculture the traders wanted more geoduck, lobsters and some species of grouper such as the giant and tiger groupers.

- It appeared from the plans for expansion that the operators were not concerned or aware of the impact this enormous fish market might have on the existing marine environments of not only China but of the countries from which they import the various species.

Annex 1 – Workshop agenda

6 March	Arrival of participants	
19:00–21:00	Pre-registration	

7 March	Opening session	
08:00–08:30	Registration	All participants
08:30–08:40	Welcome remarks	Chinese Gov. Rep.
	Workshop overview	FAO/NACA
08:40–09:00	Purpose of meeting, expected inputs/outputs	
	Workshop procedure and arrangements	
09:00–09:20	Group picture / Tea break	
09:20–09:30	Introductions	All participants
	Workshop Session I – Thematic Regional Reviews	
09:30–10:00	Mariculture products demand and markets	Sudari Pawiro
10:00–10:30	Livelihood opportunities and needs	Elizabeth Mayo Gonzales
10:30–11:00	Technology transfer mechanisms and communications	Simon Wilkinson
11:00–11:30	Mariculture species and farming technologies	Mike Rimmer
11:30–12:00	Better management of the sector for sustainability – an overview and discussion session	Michael Phillips and Rohana Subasinghe
12:00–13:00	Lunch break	
	Workshop Session II – Country Experiences	
13:00–15:00	Country/territory reviews	Country participants
15:00–15:30	Discussion session – key common issues & opportunities for cooperation	Country participants
15:30–15:45	Tea break	
	Workshop Session III – Special Presentations and Perspectives	
15:45–16:00	Chinese market review	Gao Jian
16:00–16:15	Mariculture in northern China	Chang Yaqing
16:15–16:30	Cage culture review in China	Jiaxin Chen
16:30–16:45	Development of seafarming in India	Vishnu Bhat
16:45–17:00	SEAFDEC support to aquaculture programmes	Siri Ekmaharaj
17:00–17:15	Perspective from the World Wildlife Fund	Aaron McNevin
17:15–17:30	SEAPLANT Network: An initiative of IFC-PENSA	Iain Neish
17:30-17:45	Health and disease in aquatic animals	Zilong Tan
17:45–18:15	Integrated mariculture: Its role in future aquaculture development	Max Troell
	Other experiences and final discussion	All participants
18:00–18:05	Announcement from organizers	Secretariat

8 March	**Workshop session IV – Working groups**
08:30–09:00	Introduction to Working Group tasks and expected outputs
09:00–12:00	Working Group sessions:
	Group 1: Markets, demand and trade: the demand side
	Group 2: Livelihoods, technology transfer and communications: the people and network
	Group 3: Mariculture species and systems: the supply side Major issues, Better management and Future cooperation
12:00–13:00	Lunch break
13:00–15:00	Working Group discussions (Cont'd)
15:00–15:30	Tea break
15:30–17:00	Plenary presentations by Working Group of progress to be followed by plenary discussion sessions

9 March	**Working session V – Farmer dialogue**
08:00–10:00	Depart Guangzhou for Nan'ao Bay near Shenzhen by coach
10:00–16:30	Visit mariculture site in Nan'ao Bay by boat
	Lunch break
	Mollusc and marine fish farmer dialogue:
	Working Groups will incorporate the outcomes from the farmer dialogue into their working documents.
16:30–18:00	Visit land-based aquaculture in Dongguan
18:00–20:00	Dinner and back to Guangzhou

10 March	**Working session VI – Trade and market dialogue**
08:30–12:00	Trade and market dialogue:
	Participants visit Huangsha Live Seafood Market in Guangzhou; discussion session with traders, processors and buyers on mariculture marketing and trading issues.
13:00–14:30	Lunch break
15:30–17:30	Discussion session to include selected/lead farmers, farmer group and market representatives to consider/develop regional cooperation programme. Farmer and trade representatives present their recommendations for regional cooperation followed by final discussions.

11 March	**Working session VII – Way forward**
09:00–11:00	Final presentation by Working Groups of the regional programme and discussion on the way forward
11:00–12:00	End of workshop. Closing remarks

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Annex 3 – Interventions from the final workshop session

The final session of the workshop included a number of interventions from participants concerning future directions and mechanisms for regional cooperation in the development of mariculture in the Asia-Pacific region. These interventions include various suggestions, priorities and commitments and provide an important basis for further development of a regional mariculture cooperation.

Australia

The research and development programme (R&D) of the Australian Center for International Agricultural Research (ACIAR) has been actively cooperating in the region in various aquaculture subjects and locations. There is willingness and interest to engage in further regional cooperation. Some of the recent activities and recommended future areas of cooperation include:

- Grouper hatchery technology programme;
- Pelleted feed development;
- Asia-Pacific Marine Finfish Aquaculture Network (APMAN) model for networking with other mariculture commodities;
- Indonesia training on feed development;
- Environmental impact assessment for cage culture, which can be an EIA model for the region, especially strategies and GIS;
- Marketing study (e.g. with Australian National University, Canberra):
  - Price and demand study,
  - Consumer study (taste, wild vs. aquaculture);
- Viral nervous necrosis (VNN) study (Sydney University);
- Development of management systems for VNN.

Bangladesh

Compared to the other countries, Bangladesh has a less developed mariculture sector. Establishment of hatchery, nursery and grow-out systems for seabass, milkfish and bivalves are country priorities for which cooperation and support are needed.

China

Mariculture is well developed in the country and there are numerous opportunities for cooperation with other countries in the region as follows:

Needs for regional cooperation

- Utilization of the open/deep-sea area. There are plans for development of deep-sea cage culture in the South China Sea;
- Value addition;
- Diversification of commercial species. There is a long list of potential species in China and many more species are of interest for commercial-scale development;
- Improvement of abalone production technology. Production is currently 3 000–4 000 tonnes but suffering from disease and insufficient seed supply;

- Cobia has been cultured for two years, but has not become a popular commodity in the country;
- Training in feed processing and vaccine production for marine finfish.

Offers for regional cooperation

- Transfer of ongoing seaweed farming technologies to other countries;
- Training course can be offered for sea cucumber and bivalve hatchery production (e.g. Yantai Fisheries Institute);
- Shanghai University has ongoing studies on policy, marketing, resources and environmental economics. There is an opportunity for cooperation on such issues as "environmental policy development for mariculture".

India

Needs for regional cooperation

- Although extension materials are available, further demonstrations are needed for successful extension;
- Training for trainer and farmer level (on marine finfish hatchery and cage culture); Regional tools are needed for the policy to farmer level.
-

Offers for regional cooperation

- Andaman mariculture and cooperation with NACA and FAO;
- Marine fish and other mariculture.

India, Marine Products Export Development Authority (MPEDA)

Under-development/Needs for regional cooperation

- Cooperation on production already exists (e.g. barramundi with Australia);
- Cooperation is needed on market access.

Iran (Islamic Republic of)

Needs for regional cooperation

- Marine cage culture management;
- Marine finfish hatchery development;
- Marine finfish processing;
- Feed development.

Offers for regional cooperation

- Sharing of experience on sturgeons, Caspian salmon, blacklip pearl oyster, yellow seabream, grey grouper.

Japan

Offers for regional cooperation

- Information sharing (e.g. establish a mechanism to translate and disseminate journals and papers in English);
- Training courses;
- Sharing of stock enhancement experiences, including seed production.

Malaysia

Needs for regional cooperation

- Broodstock improvement (domestication and genetic improvement);
- Low-cost feed formulation technologies and nutrition;
- Live feed production development (including copepods);
- Hatchery production of marine finfish (groupers) and recirculation hatchery technologies;
- Sea cucumber and oyster production systems.

Philippines

Needs for regional cooperation

- Mollusc hatcheries and farming technologies;
- Hatchery for sea cucumber;
- Hatchery for marine finfish (grouper, etc.).

Offers for regional cooperation

- Hatchery and production technologies for milkfish;
- Seaweed (*Eucheuma* spp.) culture.

Republic of Korea

Needs for regional cooperation

- Special study on market in China;
- Mariculture system, feed development;
- Food safety guideline;
- Food safety (e.g. heavy metal contamination in eel) due to environmental degradation;
- Formation of producer's association to work together and to share information.

SPC

Offers for regional cooperation

- Natural biodiversity, marine ornamental study;
- Larval collection experiences;
- Experiences in pearl farming environmental planning using GIS;
- Biosecurity experiences.

SEAFDEC

Offer for regional cooperation

- Cooperation for development of farm standards, food safety and ecolabeling.

SEAPLANT

Offer for regional cooperation

- Looking to expand the SEAPLANT network to whole region and willing to cooperate with NACA;
- Use of seaweed as an ingredient in aquaculture feed.

SINTEF

Offer for regional cooperation

- Six years capacity-building experience in Viet Nam;
- Willing to facilitate in regional cooperation;
- Topics of possible cooperation:
  - Cage development (for shallow water, hence mooring)
  - Harvesting and post-harvesting handling
  - Experience from salmonid culture
  - Tropical seaweed
  - Logistic traceability experience from salmon

Thailand

Needs for regional cooperation

- Longline technology for bivalves;
- Broodstock and hatchery for finfish including groupers;
- Establishment of closed recirculation system for marine finfish broodstock, nursery and grow-out system;
- Large-scale offshore cage culture technologies;

- Small-scale (low cost) bivalve hatchery operation (instead of existing complicated extensive system).

Offer for regional cooperation

- Food safety training;
- Hatchery for molluscs (abalone and *Babylonia*);
- Hatchery for seabass and some grouper species;
- Seafood processing training, which is ongoing for local personnel.

Viet Nam

Needs for regional cooperation

- Improved hatchery technologies for marine finfish;
- Marine finfish disease prevention and treatment;
- Offshore cage culture technologies.

FAO

- This workshop was delivered from the FAO regular programme and aims at the development of a regional platform for cooperation. The opportunity is now there for institutions and countries to cooperate based on this platform. For example, a regional collaborative approach is needed to effectively tackle environmental issues;
- An FAO project in Micronesia is assisting development of biodiversity management plans for aquaculture. Management of transboundary risks may be useful to the region;
- A better management practices (BMP) approach is encouraged along the lines of the shrimp consortium. The International Principles on Shrimp Farming and the Environment will be submitted to the FAO subcommittee on aquaculture meeting in September 2006;
- An overall management framework for governments, with the collaboration of other stakeholders, is required to formulate policies and regulations for the mariculture sector. This may be another common issue for cooperation;
- Food safety and quality in mariculture products are needed;
- Labeling and certification of aquaculture products are needed.

NACA

- Based on the recommendations, NACA will work with FAO and its members to develop the regional mariculture cooperation to assist countries of the region in development of sustainable mariculture.

The next step is to work together to prepare clear and practical workplans and projects to take the process forward.

Annex 4 – Selected mariculture photos

FIGURE 1
Oyster longline culture, Republic of Korea
(Photo: Kwang-Sik Choi)

FIGURE 2
Oyster harvesting, Republic of Korea
(Photo: Kwang-Sik Choi)

FIGURE 3
Oyster harvest, Shizugawa Bay, Japan
(Photo: Thuy T. T. Nguyen)

FIGURE 4
Spiny lobster cage culture, Yao Noi, Thailand
(Photo: Koji Yamamoto)

FIGURE 5
Lobster packing, Nha Trang, Viet Nam
(Photo: Sih Yang Sim)

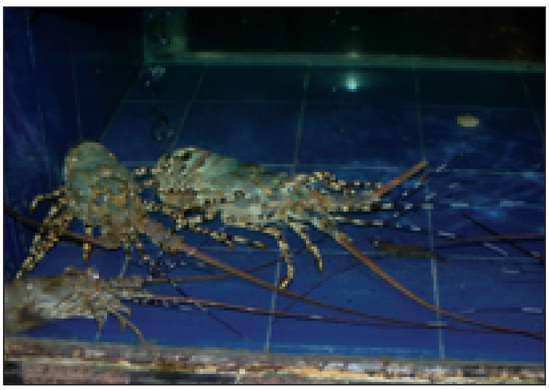

FIGURE 6
Live seafood market, Guangzhou, China
(Photo: Hassanai Kongkeo)

FIGURE 7
Seaweed harvesting, Hainan Bay, China
(Photo: Hassanai Kongkeo)

FIGURE 8
***Eucheuma* aquaculture, Viet Nam**
(Photo: Flavio Corsin)

FIGURE 9
***Eucheuma* culture-line preparation, Viet Nam**
(Photo: Flavio Corsin)

FIGURE 10
Ornamental fish hatchery, Krabi, Thailand
(Photo: Koji Yamamoto)

FIGURE 11
Scooping seaweeds and yellowtail fry, Japan
(Photo: Makoto Nakada)

FIGURE 12
Sorting yellowtail juvenile catch, Japan
(Photo: Makoto Nakada)

FIGURE 13
Grouper farm, Malaysia
(Photo: Koji Yamamoto)

FIGURE 14
Live groupers on display, Malaysia
(Photo: Koji Yamamoto)

FIGURE 15
Fish cage houses in Hainan Bay, China
(Photo: Hassanai Kongkeo)

FIGURE 16
Fish cage farming, Hainan, China
(Photo: Hassanai Kongkeo)

FIGURE 17
Lobster fixed cages, Nha Trang, Viet Nam
(Photo: Sih Yang Sim)

FIGURE 18
Farmer preparing fish feed, Cat Ba, Viet Nam
(Photo: Sih Yang Sim)

SECTION 1

Thematic regional reviews

Regional review on mariculture: products demand and markets

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Pawiro, S. 2008. Regional review on mariculture: products demand and markets. In A. Lovatelli, M.J. Phillips, J.R. Arthur and K. Yamamoto (eds). FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11 March 2006. *FAO Fisheries Proceedings.* No. 11. Rome, FAO. 2008. pp. 41–63.

INTRODUCTION

Over the past few years there have been tremendous developments in the seafood markets in this region. The most significant changes have taken place in the retail sector, where more varieties of fish are being sold that are locally produced or imported, more innovative presentations and product forms (whole, gutted, steak, fillet, breaded, frozen, dried, canned, ready-to-eat, preserved, etc.) are seen, more affordable and better quality products are offered (even imported products such as salmon and cod are getting cheaper); and more western-style seafood products are available (fish burger, fish sandwich, breaded products, white meat fish fillet, fish and chips, etc.).

Under this fast-changing scenario, particularly in Southeast and East Asian countries, aquaculture plays an increasingly important role in providing more supplies at affordable prices. Asia is the largest producer of cultured fish and also a large consumer of seafood; thus, the role of this sector in this part of the world is more important than in other regions. With this backdrop, this paper reviews the market trends for fishery products in the region with emphasis on marine aquaculture products.

GLOBAL DEMAND TRENDS

As a result of population growth and socio-economic development, global demand for fish and fishery products has continued to grow at the rate of 4.3 percent per year for the past two decades. Global foodfish supply (for human consumption) increased from around 53.4 million tonnes in 1981 to more than 104 million tonnes in 2003, resulting in an increase in the average per capita fish consumption (apparent consumption) from 11.8 kg to around 16.5 kg during that period. Demand for fishery products is expected to remain strong in the future, and the average apparent fish consumption is expected to reach around 18.4 kg/caput/year by 2010 and 19.1 kg/caput by 2015 (Table 1).

TABLE 1
Past and projected fish consumption (kg/caput)

Group	1961/1965	1981/1985	1991/1995	2001	2010[1]	2015[1]
Finfish	8.2	9.9	10.6	12.1	13.7	14.3
Others	1.3	2.2	3.2	4.2	4.7	4.8
Total	9.5	12.1	13.8	16.3	18.4	19.1

[1] Projection.

Figure 1
Total fish products supply in 2003.
(Source: FAO)

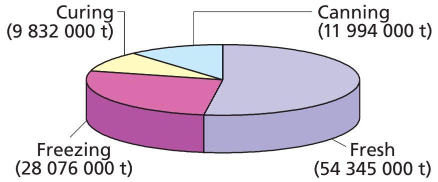


Figure 2a
Total fish products supply in developing countries in 2003.
(Source: FAO)

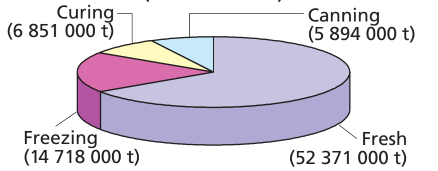
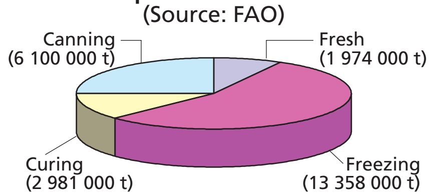


Figure 2b
Total fish products supply in developed countries in 2003.
(Source: FAO)



From a total of more than 104 million tonnes of fish used for human consumption in 2003, fresh/chilled fish products were preferred by consumers. More than 52.1 percent of the total foodfish supply was sold in this form. Frozen fish products came second, accounting for around 26.9 percent, followed by canned (11.5 percent) and cured fish, including salted products (9.4 percent) (Figure 1).

There is, however, a big difference in fish consumption patterns between developed and developing countries. In developed countries, the large proportion (54.7 percent) of fish products was sold in frozen forms, followed by canned (25.7 percent) and cured (12.2 percent), and the rest was fresh fish (6.2 percent). In contrast, in developing countries, around 65.6 percent of fish for human consumption was sold in fresh form, followed by frozen products (18.4 percent), cured products (8.6 percent) and canned fish (7.4 percent) (Figures 2a and 2b).

By species groups, freshwater and diadromous fish were the main species group widely consumed, and their contribution to per caput apparent consumption increased from 1.6 kg in the early 1960s to 4.7 kg in 2001 (Table 2). This was mainly the result of an increase in supply from aquaculture. Similarly, the contribution of crustaceans and molluscs also increased because of the fast-growing production from the aquaculture sector.

However, the contribution of marine demersal and pelagic fishes has been dwindling as a result of declining fish stocks in many parts of the world.

TABLE 2
Global apparent fish consumption (supply) by main species groups (kg/capita) (Source: FAO)

Group	1961/1965	1981/1985	1991/1995	2001
Freshwater & diadromous	1.6	2.1	3.2	4.7
Demersal	2.9	3.3	2.9	2.9
Pelagic	2.6	3.1	2.9	3.0
Other marine (unspecified)	1.1	1.4	1.6	1.5
Crustaceans	0.5	0.8	1.1	1.5
Molluscs	0.6	1.1	1.6	2.1
Cephalopods	0.2	0.3	0.4	0.5
Other aquatic animals	0	0	0.1	0.1
Total	9.5	12.1	13.8	16.3

DEMAND TRENDS IN MAJOR MARKETS

Demand for fishery products has been growing steadily in major markets, namely in the United States of America and European Union (EU), but is somewhat stagnant in Japan. Demand for cultured species like shrimp, tilapia and catfish is growing faster, particularly in the United States of America market.

Per capita fish consumption in the United States of America grew consistently over the past four years from 14.8 lb in 2001 to 16.6 lb (7.55 kg) in 2004, representing an increase of 12.2 percent during the period (Table 3). Fresh and frozen fish products were the main driving force, contributing 71 percent of the total consumption, while the consumption of canned and cured products is on the decline.

Fresh and frozen fishery products, dominated by shrimp and tilapia, contributed significantly to this growth. In contrast, consumption of canned fishery products declined, including canned tuna, which is the second most favourite seafood in the USA.

The demand for farmed fish has been on the rise, especially for shrimp, salmon, catfish and tilapia. Shrimp remained the favourite species (4.20 lb/caput) (Table 4) in the list of "Top Ten" fishery products, followed by canned tuna (3.30 lb), salmon, pollack, catfish, tilapia, crab, cod, clams and flatfish. Per capita consumption of tilapia doubled in three years, from 0.317 lb in 2002 to 0.696 lb in 2004.

The demand, in edible weight, of fishery products in the United States of America totalled 2.18 million tonnes in 2004.

TABLE 3
United States of America per capita consumption of fishery products (lbs of edible meat) (Source: NMFS, 2005)

Year	Fresh & frozen	Canned	Cured	Total
2000	10.2	4.7	0.3	15.2
2001	10.3	4.2	0.3	14.8
2002	11.0	4.3	0.3	15.6
2003	11.4	4.6	0.3	16.3
2004	11.8	4.5	0.3	16.6

TABLE 4
United States of America per capita consumption of selected fishery products (lbs) (Source: NMFS, 2005)

Year	Fillets & steaks	Sticks & portions	Shrimp
2000	3.6	0.9	3.2
2001	3.7	0.8	3.4
2002	4.1	0.8	3.7
2003	4.3	0.7	4.0
2004	4.6	0.7	4.2

As demand for fishery products increases, United States of America imports of edible fish in 2004 increased marginally to US$11.3 billion compared to US$11.1 billion the year before. Last year, the total imports into the United States of America set a new record at 2 393 673 tonnes valued at US$12.2 billion.

Meanwhile in Japan, demand for fishery products is stagnant or even tends to decline, mainly because of the country's long economic recession during the 1990s, changing lifestyle of the younger generation and declining domestic fish supply. Per capita fish food supply (apparent consumption) declined from the record high at 72.5 kg in 1994 to 68.6 kg in 2002. While per capita consumption of seaweed has remained stable at around 1.4–1.5 kg over the past few years, the consumption of fish and shellfish declined from 71 kg in 1994 to 67.1 kg in 2002 (Table 5).

TABLE 5
Japan: per capita fish food supply (apparent consumption) (kg) (Source: MAFF, 2004)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Fish & shellfish	67.8	71.0	71.0	69.7	66.4	64.3	65.6	67.2	69.2	67.1
Seaweed	1.3	1.5	1.4	1.4	1.4	1.4	1.5	1.4	1.4	1.5
Total	69.1	72.5	72.4	71.1	67.8	65.7	67.1	68.6	70.6	68.6

Household surveys also suggest the same trend. Average consumption of fishery products at the household level declined over the years from 66.5 kg per year in 1993 to 56.3 kg in 2002. Household consumption of all types of fishery products also declined (Table 6).

TABLE 6
Japan: average consumption of fishery products at household level (kg) (Source: MAFF, 2004)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Fresh/frozen	49.9	47.5	47.8	45.6	45.6	45.1	44.1	43.6	42.5	43.9
Salted/dried	13.7	13.0	12.8	12.6	12.3	12.0	11.5	11.1	10.9	10.7
Seaweed (dried/prepared)	2.9	2.7	2.7	2.7	2.7	1.9	1.8	1.70	1.7	1.7
Total	66.5	63.2	63.3	60.9	60.6	59.0	57.4	56.4	55.1	56.3

Around 47 percent of fish supply into the Japanese market came from imports, while the rest was from domestic production, which has been declining over the years. Imports of fishery products, in the meantime, have been more or less stagnant for the past three years after reaching the highest record at 3.82 million tonnes in 2001. There were some signs of recovery during 2004 when total imports reached almost 3.5 million tonnes worth US$15.1 billion. In 2005 the overall imports were slightly down in terms of quantity to 3.34 million tonnes but increased in value to ¥ 1 669 billion.

The positive trend comes from the growing imports of more value-added products, especially for farmed shrimp. In 2004, Japan imported 412 447 tonnes of high-value prepared products (excluding raw material) at a value of US$2.85 billion compared to 355 271 tonnes and US$2.35 billion in 2003. A large quantity of these is comprised of shrimp, fish and cephalopod-based products. During 2001–2004, imports of prepared (value-added) fishery products into Japan increased by 20.5 percent or 70 230 tonnes in quantity and 26 percent in value.

The demand for seafood in Europe is also growing, and per capita consumption within the 25 EU member countries is expected to increase by 1–12 percent from 2005–2006 (FAO). The general seafood consumption trend up to 2004 showed positive growth with significant increase in the consumption of convenience products. Economic growth, health consciousness, changing life styles and better distribution through modern retail outlets are the main forces behind the growth.

Demand for tropical farmed products such as shrimp is growing rapidly in the EU markets as reflected by increasing imports. The import of fresh and frozen shrimp reached a record level at 558 200 tonnes in 2003, then slightly declined to 554 000 tonnes in 2004, partly due to the antibiotic issue affecting supplies from some countries in Asia. In 2005, after the antibiotic issues disappeared and the EU had lifted the ban on Chinese shrimp in July 2004, the importation of shrimp increased in the main market (i.e. Spain, Italy, France, Germany and the United Kingdom). For example, as of October 2005, imports of frozen warmwater shrimp into the United Kingdom totalled 32 055 tonnes, or an increase of 6.8 percent from the same period of 2004. Similarly, imports of frozen warmwater shrimp into Spain increased by 8.2 percent last year, reaching 104 119 tonnes by October. The People's Republic of China is now the largest supplier of shrimp to Spain, overtaking Brazil. In Italy, for the period January–September 2005, imports of warmwater frozen shrimp increased by 9.9 percent compared to 2004, amounting to 34 148 tonnes.

Based on a study sponsored by the Food and Agriculture Organization of the United Nations (FAO), the future fish consumption in the EU will show three different trends: (i) consumption of cured fish and fresh/chilled fish will be more or less stable; (ii) consumption of crustaceans, molluscs, fish fillet and prepared/preserved products will increase; and (iii) consumption of frozen produce will decrease.

The highest consumption growth is predicted to be for crustaceans, especially shrimp, and fish fillets.

DEMAND TRENDS IN SOUTHEAST AND EAST ASIA

Asia, particularly Southeast and East Asia, is a unique region, being the largest producer, exporter and importer of fishery products, especially aquaculture products. The following facts speak for themselves: The ten Association of Southeast Asian Nations (ASEAN) member countries plus East Asia (the People's Republic of China, Japan, China, Hong Kong SAR, Taiwan PC and the Democratic People's Republic of Korea), altogether in 2003:

Produced	:	79.2 million tonnes fish (60% of world total)
Cultured	:	46.1 million tonnes (84% of world total)
Exported	:	6.95 million tonnes of fishery products (24.8%) US$7.7 billion (27.9% of world total)
Imported	:	9.62 million tonnes (33.3% of world total) US$21.7 billion (31.8% of world total)
Per capita fish supply	:	39.6 kg (world 16.3 kg)

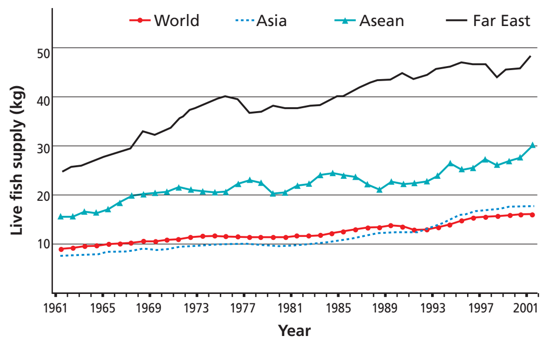
The demand for fishery products is high and growing in this region (except in Japan, as discussed earlier), as the consumers generally have a strong preference for fish, and there are abundant supplies both from wild and cultured fish; strong purchasing power (except in some countries in ASEAN); high consumption both at the household level and catering sectors; broad preferences for different species and forms (marine, freshwater, live, fresh, cured, dried/salted and also canned and frozen products); a booming tourism industry that stimulates demand for high-value species; and growing modern retail outlets and rapid economic growth (China, Viet Nam, Singapore, etc.).

In this region, people eat fish and fishery products almost on a daily basis, and thus the average fish consumption is far above the world level. In ASEAN countries, apparent fish consumption was around 30.5 kg/caput in 2001, while at the same time the world's average was only 16.3 kg/caput (Figure 3).

In Far East Asian countries, the average apparent fish consumption was 48.7 kg/caput, with China as the main force behind the growth. According to the Chinese Ministry of Agriculture, average per capita fish consumption increased from 16.4 kg in 2001 to 18.1 kg in 2003, with consumption in coastal areas reaching more than 40 kg/caput (USDA-FAS, 2005).

The demand growth in this region is driven by an increasing demand for almost all types of product form. In addition to the high consumption of live and fresh fish products, the demand for frozen and chilled convenience products, canned (especially tuna) and dried products is also growing rapidly. Frozen breaded fillet and steak products are a common sight in supermarkets throughout the region. There is also a growing demand for canned products (especially canned tuna), which are sold in various tastes and recipes. Various dried and "tit-bit" fish products are also popular in Southeast Asia.

Figure 3
Per caput live fish supply
(Source: FAO)



The aquaculture sector plays a major role in fish food supply in this region, and in China the contribution of farmed fishery products is higher than wild fish. Reportedly, 67 percent of fish food supply in China currently comes from aquaculture, and this is expected to increase as much as 70 percent within the next five years. In other countries in this region, the contribution of aquaculture is generally lower than in China.

The Southeast and Far East Asian countries produced more than 46.1 million tonnes of cultured aquatic products in 2003 (including seaweed), contributing more than 84 percent to the global production. With the inclusion of China, aquaculture contributed around 58 percent of the total fish production in the region, indicating the importance of the sector in fish supply. Marine aquaculture (including brackishwater) contributed 57 percent to the total aquaculture production in 2003. The bulk of the marine aquaculture production is seaweed; however, shrimp, bivalves and finfish are also considered important cultured species in the region.

With the exception of shrimp and seaweed, a large proportion of marine cultured species in this region is consumed locally or traded among countries in the region. Well-known cultured marine finfish such as grouper, snapper, Asian seabass and milkfish are mainly consumed within the country or exported to neighbouring markets such as China, Hong Kong SAR (grouper), Malaysia and Singapore. Regional trade of farmed bivalves such as the exportation of blood cockle from Malaysia to Singapore and Thailand, and of clams from China to Japan and the Democratic People's Republic of Korea, is also significant.

While farmed shrimp (*Penaeus monodon* and *Litopenaeus vannamei*) are mainly exported to developed markets (e.g. United States of America, Japan and Europe), local consumption and regional trade are also increasing.

Nowadays, live, fresh, frozen and value-added shrimp products are widely sold in supermarkets in this region and often used as promotional items. Increasing supply (mainly of *L. vannamei*), better distribution, increasing consumer income, wider use in the catering sector and increasing trade barriers (e.g. anti-dumping duty, safety and antibiotic issues) in developed markets are the main factors behind the growing domestic market for farmed shrimp. The region is also becoming an important market for shrimp raw material used for reprocessing.

Consumption of seaweed products is also high, particularly in Japan, the Democratic People's Republic of Korea and China. The food industry is expanding rapidly; hence there is also a growing market for agar and carrageenan in the region. Japan, for example, consumed more than 200 000 tonnes of edible seaweed (dried *nori*, *kombu*, etc.), with more than 52 000 tonnes being imported. While China is the largest producer of seaweed and seaweed products, the country is also becoming an important market for carrageen-seaweed for reprocessing. The Democratic People's Republic of Korea, meanwhile, exports a large amount of dried *nori* and *hijiki* (fusifome), mainly to Japan. The Philippines, Indonesia and Malaysia are the main producers of dried seaweed and semi-carrageenan products exported mainly to Europe and the USA.

REGIONAL SEAFOOD TRADE AND MARKETS

Global trade of fish and fishery products reached US$68.3 billion (import value) in 2003, with an average increase of approximately 5.1 percent per year for the past decade. At the same time, the global export value also increased by 5.4 percent annually, totalling US$63.5 billion in 2003 (FOB price). Despite stagnant demand in some markets, especially in Japan, the overall global market shows a positive trend for fishery products (Table 7).

TABLE 7
Global trade of fish and fishery products, 1997–2003 (Source: FAO, 2005a)

Exports	1997	1998	1999	2000	2001	2002	2003
Quantity (tonnes)	24 525 564	22 599 429	24 230 015	26 434 946	27 550 549	27 410 474	28 008 554
Value (US$1 000)	53 633 402	51 392 023	53 114 282	55 579 042	56 459 664	58 494 481	63 508 377

Imports	1997	1998	1999	2000	2001	2002	2003
Quantity (tonnes)	23 594 120	22 557 088	24 226 213	26 549 699	27 886 775	28 053 542	28 563 300
Value (US$1 000)	57 573 408	56 108 158	58 574 571	60 995 816	60 558 951	62 500 451	68 261 513

Southeast and Far East Asia is still one of the growing markets, despite the fact that fish consumption is already high. It is estimated that total imports of fishery products into this region could have reached as much as US$25 billion in 2004, representing an average growth of 2.6 percent since 1993, with Japan, China, Thailand and the Democratic People's Republic of Korea being the main importing countries. Excluding Japan, the import of fishery products into the region was estimated at approximately US$7 billion in 2004, indicating a tremendous annual growth of about 9 percent since 1993, with China and Thailand as the main forces.

Meanwhile, as the main producers of fishery products, exports from Southeast and Far East Asian countries/territories also increased consistently over the years from US$12.7 billion in 1993 to US$17.7 billion in 2003 (Table 8). This represents an average annual growth of 4 percent in value terms. It is estimated that the total export value from the region reached US$20 billion in 2004.

In ASEAN countries, trade of fishery products has been consistently growing since the economic crisis began and in 1998 when exports and imports hit their low levels. Export of fishery products from ASEAN countries increased from US$7.75 billion in 1998 to US$8.94 billion in 2003, i.e. up by 15.4 percent during the period.

TABLE 8
Exports of fishery products from Southeast and Far East Asia by country/territory, 2000–2004 (Q=tonnes; V=US$1 000) (Source: FAO, 2005a)

Country		2000	2001	2002	2003	2004[1]
Brunei Darussalam	Q	285	149	92	144	NA
	V	296	334	459	706	NA
Cambodia	Q	43 636	38 454	52 752	56 957	NA
	V	37 691	31 308	32 071	34 744	NA
China	Q	1 516 404	1 928 966	2 057 424	2 082 080	2 420 565
	V	3 706 339	4 106 214	4 600 704	5 362 366	6 966 483
China, Hong Kong SAR	Q	55 733	49 402	48 446	46 229	NA
	V	76 089	52 859	50 313	47 365	NA
Indonesia	Q	490 416	457 913	539 302	830 383	902 358
	V	1 610 291	1 560 078	1 516 537	1 579 783	1 780 833
Japan	Q	221 868	312 769	306 353	364 655	321 983
	V	832 088	794 897	817 593	952 419	1 369 425
Laos	Q	4	30	74	24	NA
	V	29	78	256	26	NA
Malaysia	Q	95 435	126 229	203 327	160 262	238 229
	V	200 469	220 126	381 983	256 197	545 526
Myanmar	Q	111 843	159 705	158 904	72 850	NA
	V	185 030	198 011	248 343	142 566	NA
Philippines	Q	213 839	170 091	171 279	201 630	NA
	V	449 376	414 430	453 030	465 734	NA
Republic of Korea	Q	530 870	431 319	424 905	418 799	406 435
	V	1 489 803	1 253 300	1 138 346	1 102 081	1 278 638
Singapore	Q	112 144	102 133	88 516	86 898	90 344
	V	457 274	388 205	325 179	329 952	340 627
Taiwan PC	Q	697 851	692 264	733 616	715 705	577 375
	V	1 762 576	1 815 892	1 617 687	1 305 633	1 578 800
Thailand	Q	1 162 099	1 217 310	1 247 270	1 401 915	1 685 177
	V	4 384 437	4 054 130	3 692 158	3 919 824	4 413 750
Viet Nam	Q	302 943	392 796	493 637	508 766	531 323
	V	1 484 413	1 783 913	2 035 515	2 211 050	2 400 781
TOTAL	Q	5 555 370	6 079 530	6 525 897	6 947 297	7 500 000[2]
	V	16 676 201	16 673 775	16 910 174	17 710 446	20 000 000[2]

[1] National statistics.

[2] Estimated.

Similarly, imports to ASEAN countries have recovered tremendously since 1998, with an annual growth of around 9.6 percent in quantity and 8.4 percent in value, reaching over 2 million tonnes worth a total of US$2.4 billion in 2003 (Table 9).

TABLE 9
Imports of fishery products into ASEAN and Far Eastern countries/territories, 2000–2004 (Q=tonnes; V=US$1 000) (Source: FAO, 2005a)

Country		2000	2001	2002	2003	2004[1]
Brunei Darussalam	Q	6 624	8 335	6 573	7 201	NA
	V	15 239	13 379	13 136	11 847	NA
Cambodia	Q	2 100	852	2 217	3 122	NA
	V	4 130	1 663	4 033	5 514	NA
China	Q	2 514 321	2 280 412	2 483 798	2 324 492	2 985 642
	V	1 820 699	1 816 022	2 226 628	2 426 254	3 239 443
China, Hong Kong SAR	Q	329 442	349 416	360 564	356 960	NA
	V	1 970 395	1 785 380	1 786 968	1 773 781	NA
Indonesia	Q	171 349	151 957	110 035	91 707	136 040
	V	101 644	93 730	79 095	76 088	154 032
Japan	Q	3 540 479	3 726 738	3 816 227	3 210 472	3 484 982
	V	15 742 561	13 649 228	13 862 980	12 623 644	15 128 617
Laos	Q	2 510	3 142	2 725	3 164	NA
	V	2 069	2 170	1 727	2 333	NA
Malaysia	Q	322 923	353 400	464 172	386 586	406 190
	V	307 340	336 705	400 345	377 504	509 211
Myanmar	Q	1 536	806	723	1 393	NA
	V	2 153	932	1 354	2 037	NA
Philippines	Q	248 407	180 992	217 069	168 846	NA
	V	111 596	71 362	92 524	86 445	NA
Republic of Korea	Q	755 301	1 068 715	1 191 622	1 240 217	1 280 915
	V	1 398 606	1 648 642	1 882 849	1 958 477	2 261 356
Singapore	Q	182 349	172 994	173 797	185 637	230 446
	V	566 286	489 009	512 404	542 383	744 842
Taiwan PC	Q	454 496	423 693	388 207	377 958	387 378
	V	578 932	565 893	496 541	494 222	531 699
Thailand	Q	813 789	977 350	1 006 011	1 078 620	1 255 223
	V	826 699	1 072 467	1 079 379	1 133 815	1 283 025
Viet Nam	Q	19 547	19 189	39 084	86 311	NA
	V	24 272	32 508	99 656	164 216	NA
TOTAL	Q	9 365 173	9 717 991	10 262 824	9 522 686	10 500 000[2]
	V	23 472 621	21 579 090	22 539 619	21 678 560	22 000 000[2]

[1] National statistics.
[2] Estimated.

Regional trade within ASEAN, between China – ASEAN and between South Asia–ASEAN/China is also growing, even though the value is relatively small compared with trade with the developed markets (Table 10). In 2003, regional trade (exports) within Far East and Southeast Asian countries (excluding China and developed markets like Japan) was less than US$1 billion or only 9.2 percent of the total region's export value. China's export to Southeast and Far East Asian countries accounted for more than US$1 billion or 15.4 percent of the country's total exports in the same year.

Meanwhile, only around 7.5 percent of the total exports value of fishery products from South Asia was destined to Southeast and Far East Asia, while to China it was 6.1 percent.

TABLE 10
Regional trade flows (export values in US$1 000) (Source: FAO, 2005a)

Destination by region	From					
	China		East and SE Asia		South Asia	
	Value	%	Value	%	Value	%
North America	1 234 460	(19)	3 261 577	(31.8)	540 239	(26.7)
European Union (25)	573 935	(8.9)	1 130 667	(11.0)	595 390	(29.5)
Other Western Europe	5 893	(0.1)	69 799	(0.7)	10 375	(0.5)
Other developed countries	3 129 819	(48.3)	3 672 899	(35.8)	463 224	(22.9)
South Asia	2 487	(0.04)	26 666	(0.3)	37 329	(1.8)
East and Southeast Asia	1 000 499	(15.4)	948 940	(9.2)	152 378	(7.5)
China	377 342	(5.8)	655 354	(6.4)	122 405	(6.1)
Others	151 454	(2.3)	497 525	(4.8)	99 852	(4.9)
Total	6 475 882	(100)	10 263 427	(100)	2 021 192	(100)

In the future, regional trade of fishery products is expected to grow faster as a result of growing demand in the region, the on-going trade liberalization process (ASEAN–China, Free Trade Areas, etc.), increased production (particularly from aquaculture), and external factors such as increasing trade and non-trade barriers from developed markets.

The following sections present brief reviews on trade and market trends for selected marine aquaculture products in the region.

SHRIMP

Litopenaeus vannamei (white leg shrimp) and *Penaeus monodon* (black tiger shrimp) have been two main forces behind the growth of the global shrimp industry and market for the past decade. Together, both species contributed around 77 percent of the total cultured shrimp production in 2003. In the global shrimp trade, even though there is no official figure, together *L. vannamei* and *P. monodon* are estimated to contribute around 50–60 percent of the shrimp quantity traded internationally.

Farmed *L. vannamei* production has increased considerably over the past ten years, from only 109 397 tonnes in 1993 to 723 858 tonnes in 2003. Asia is mostly responsible for the growth, its share growing from almost nothing before 2000 to approximately 64 percent in 2003.

Farmed *P. monodon* production, on the other hand, has been fluctuating for the past ten years due to disease-related problems, and the annual production growth was only around 3.4 percent during the period 1993 to 2003. Thus in Asia, over the past two years, the growth of the shrimp-farming industry has mainly been accelerated by the growth of *L. vannamei* farming, which has become an important alternative to *P. monodon*.

As aquaculture has made more shrimp available at affordable prices to end users, demand for shrimp in general has increased in the global market, especially in the main traditional shrimp markets in the United States of America and Western Europe, but has leveled off in Japan, the former leading market. As of 1997, the USA replaced Japan as the leading market for shrimp, and Japanese imports, especially of frozen shrimp, declined over the years due to the country's lengthy economic recession. Nevertheless, in 2004, the overall shrimp imports into Japan increased by 6.5 percent compared with 2003, mainly due to the appreciation of the Yen and the anti-dumping case in the United States of America against six shrimp-producing nations. Imports of fresh and frozen shrimp also slightly increased by 3.5 percent in 2004, amounting to 242 037 tonnes, but then decreased slightly to 233 376 tonnes last year (Table 11).

Traditionally, Japanese consumers have a strong preference for *P. monodon* and the market is still dominated by this species, in both the shell-on and value-added products such as *nobashi* and other peeled products. In the shell-on market alone, around 63.5 percent of the market share is taken by *P. monodon*, followed by white shell-on products (16 percent), consisting mainly of banana and white Indian shrimp. Farmed *L. vannamei* is mainly imported from China (particularly as peeled shrimp) and from Brazil and Ecuador. The exportation of *L. vannamei* from Ecuador, in fact, has gradually declined from more than 5 500 tonnes in 1999 to 852 tonnes last year. Brazil managed to increase its exports to 1 452 tonnes in 2002 then dropped to 1 068 tonnes in 2005. Thus, the impact of *L. vannamei* in the Japanese market, especially with regard to the *P. monodon* market, is very minimal.

TABLE 11
Japan: imports of shrimp (all types), 1998 and 2001–2005 (tonnes) (Source: Japanese Customs)

Product Type	1998	2001	2002	2003	2004	2005
Live	364	577	406	293	383	271
Fresh/chilled	85	99	36	19	33	19
Frozen, raw	238 906	245 048	248 868	233 195	241 445	232 443
Dried/salted/in brine	2 349	1 704	1 875	1 977	2 351	2 008
Cooked, frozen	10 338	14 045	13 936	13 927	16 745	17 051
Cooked & smoked	376	515	468	453	618	422
Prepared/preserved[1]	13 984	23 980	27 678	33 361	39 692	42 181
Sushi (with rice)	50	160	194	92	341	263
Total	266 038	286 128	293 461	283 318	301 608	294 658

[1] Including tempura & canned shrimp.

However, there have been changes in the consumers' preference for shrimp in the Japanese market. As the market becomes more price sensitive, demand has moved from large to medium-size shrimp, as the latter is perceived to be cheaper. This trend is more visible in the retail market. In the food service sector, sushi bars have started to respond to this trend and serve required sizes of sushi shrimp that are smaller than before. Re-processors of sushi and tempura shrimp have also started to use relatively smaller sizes of shrimp in order to accommodate the final consumer's demand pattern and affordability. This strategy works out in favour of farmed white shrimp, where the predominant counts are 51/60 and above.

In the small-size peeled shrimp market segment, especially in the catering sector, white peeled shrimp is also preferred, as it gives room for *L. vannamei* to penetrate the segment. It is also worth noting that supermarkets in Japan have started promotional sales for farmed white shrimp from China (mostly *L. vannamei*); thus we can expect the increasing popularity of *L. vannamei* in the near future. It has been reported, however, that sushi bars still prefer *P. monodon* and they are reluctant to use *L. vannamei*.

Imports of shrimp into the USA continue to set new records at 518 379 tonnes in 2004, representing an average increase of 11.2 percent per year over the past five years. Even though supplies from six countries affected by the anti-dumping duties were lower in 2004, other major suppliers such as Indonesia, Bangladesh, Mexico and Malaysia managed to fill the gap and tremendously increase their exports to the market. Imports from the six anti-dumping-affected countries dropped by 13.4 percent from 372 890 tonnes in 2003 to 322 957 tonnes in 2004, while imports from non-affected countries went up from 131 605 tonnes to 194 660 tonnes, representing an increase of almost 50 percent. Last year, shrimp imports into the USA increased by 2.7 percent over 2004, reaching 532 160 tonnes worth US$3.7 billion (for all product forms).

Imports of shrimp into the EU have also increased significantly recently, with imports into the United Kingdom, Spain, Italy, France and Germany increasing by almost 10 percent over the past five years. The popularity of warmwater shrimp (*Penaeus/Litopenaeus* spp.) has been growing rapidly in these five countries.

Generally, competition between *P. monodon* and *L. vannamei* is still limited in certain areas, especially in the small sizes and peeled market segments. Competition is more obvious between producing countries exporting *P. monodon* or *L. vannamei* to different markets.

As the main producers of cultured shrimp, both *P. monodon* and *L. vannamei*, Southeast and Far East Asian countries are also becoming increasingly important markets for shrimp. The demand for shrimp in Malaysia, Singapore, China, Hong Kong SAR, China, Thailand, the Democratic People's Republic of Korea, Indonesia and Viet Nam has increased tremendously over the years due to the following factors:

- increase in supply of farmed shrimp at lower price, especially for *P. monodon* and *L. vannamei*;
- increase in consumer income;
- changing consumer lifestyle and preferences toward healthy food;
- improved distribution channels, especially the fast growing number of modern retail outlets/supermarkets;
- increase in popularity of Japanese-style seafood restaurants;
- trade barriers enforced by importing countries (such as the anti-dumping case in the United States of America and antibiotic case in the EU) that force producers to sell their product in the domestic and regional markets; and
- wider usage of shrimp in the catering sector.

In addition to *P. monodon*, *L. vannamei* is also widely sold and consumed in China, Thailand, China, Hong Kong SAR, Singapore and Malaysia. In Malaysia, where the farming of *L. vannamei* was previously banned, *L. vannamei* is sold in supermarkets and wet markets at around RM 15–19/kg (US$4–5/kg). The ban of farming of *L. vannamei* in Malaysia was lifted in 2005. As the production has increased tremendously in China, *L. vannamei* has become abundant in local markets and its popularity is also growing.

Regional trade of *L. vannamei* is also growing as production increases; and at the same time producing countries such as China, Thailand and Viet Nam are facing anti-dumping duties in the United States of America market. Imports of shrimp into certain countries in Asia that are not affected by the anti-dumping duties increased tremendously in 2004 (Table 12). In 2004, China exported 12 069 tonnes to Indonesia, 6 540 tonnes to Malaysia and 3 976 tonnes to Singapore, representing an increase of 245.3 percent, 36.4 percent and 168.6 percent, respectively, compared to the previous year. Exports of fresh and frozen shrimp from Thailand to other countries in Asia also increased significantly by 6.9 percent in 2004 with exports to Malaysia, China, Hong Kong SAR and the Democratic People's Republic of Korea increasing by 2 500 percent, 20 percent and 29.4 percent, respectively, compared to the previous year.

TABLE 12
Asia: fresh and frozen shrimp imports (excluding dried and processed products), 1997–2004 (tonnes) (Source: National statistics)

Countries	1997	1998	1999	2000	2001	2002	2003	2004
Taiwan PC	23 239	20 337	22 977	22 561	13 568	11 978	7 281	5 110
Singapore	16 716	15 119	14 319	14 091	12 148	12 812	12 000	12 695
China, Hong Kong SAR	23 019	22 044	19 609	29 335	25 104	25 373	20 348	18 571
Malaysia	23 773	23 110	19 892	16 469	23 971	22 814	32 080	21 017[1]
Republic of Korea	9 407	2 740	4 654	6 666	12 965	22 200	21 883	25 000[2]
China	14 160	15 142	1 677	57 358	63 114	67 691	68 315	57 878
Thailand	12 199	14 492	15 247	17 808	24 124	29 448	26 524	23 745
Total Asia (excluding Japan)	120 722	108 710	103 514	164 288	174 994	192 316	188 431	164 016

[1] Frozen only.
[2] Estimate.

From the above, it can be concluded that developing the shrimp farming industry to culture both *P. monodon* and *L. vannamei* seems to be the better option at present, rather than choosing only one of them. Among the reasons are:

- both species complement each other and can reduce business risk within the industry;
- shrimp farmers would have an alternative to switch to one of them should there be any technical or marketing problems;
- in the global market, both species generally serve different market segments, and the competition is still limited in small-size segments, especially in the retail sector;
- increasing availability of cheaper shrimp (from *L. vannamei*) will create more demand on domestic markets; and
- with technology development and improvement in the production efficiency, the industry is expected to be able to cope with the declining prices and offer cheaper products in the global market.

The strong competition in the near future seems to be among *L. vannamei* producers from Latin America and Asia. Among Asian producers, China should be reviewed closely, as the country is currently the leading *L. vannamei* producer and there are indications that the country will increase its production and its presence in the global market. Even though the bulk of *L. vannamei* production is currently smaller-size shrimp (60/70 and 70/80 pc/kg), many farmers are trying to produce larger shrimp, as this is said to be economically more viable, as larger shrimp fetch higher prices and are thus more cost effective to produce. Once this effort succeeds, there will be more competition with *P. monodon* in larger market segments.

It is interesting to note that the Thai government is reportedly trying hard to increase farmed *P. monodon* production's share from currently less than 10 percent to 35 percent within the next five years.

BIVALVE MOLLUSCS

Bivalves contributed approximately 9.5 percent of the total fisheries production in 2003 (excluding aquatic plants), higher than the contribution of crustaceans (6.6 percent) and cephalopods (2.4 percent). Although the bivalve industry is important for many coastal nations, production and trade are mainly concentrated in a few countries or regions, such as the Far East (China, Japan and the Democratic People's Republic of Korea); Europe (France, Spain, Italy and Denmark); North America (the United States of America and Canada) and South America (Chile, Peru and Argentina).

The international trade in bivalves is very much regionalized, and not many countries are able to penetrate distant markets outside their regions, owing to technical barriers such as strict regulations on imports of bivalve products in major markets. As a result, bivalves' contribution to the total global trade in fish and fishery products was only around 2.5 percent in value in 2003, less than shrimp (17 percent), tuna (9 percent), salmon (6 percent) and cephalopods (4 percent).

Global bivalve production from aquaculture has consistently increased over the years, from 5.3 million tonnes in 1993 to 11.2 million tonnes in 2003, an average annual increase of 10.9 percent. As a result, aquaculture's contribution to overall bivalve production increased from 72.8 percent in 1993 to 84.0 percent in 2003. Meanwhile, the production from wild harvest has been more or less stagnant at around 1.9–2.0 million tonnes, its contribution in fact declining from 27.2 percent to 16.2 percent during the same period.

China became the single largest producer of bivalves with a production of 8.8 million tonnes in 2003, contributing 66.7 percent of the global harvest (both wild and cultured) in that year. Japan was the second largest producer, far behind China with a production of around 951 400 tonnes (7.2 percent), followed by the United States of

America (6.3 percent), the Democratic People's Republic of Korea (2.9 percent) and Spain (1.7 percent). Other main bivalve-producing countries are France, Thailand, Italy, Canada and Denmark.

In the aquaculture sector, the top five leading producers of bivalves are China, Japan and the Democratic People's Republic of Korea in Asia, and Spain and France in Europe. China contributed more than 79 percent of the global aquaculture production of bivalves in 2003.

World exports of fresh and frozen bivalves increased from 500 000 tonnes valued at US$1.30 billion in 2001 to 553 600 tonnes worth US$1.46 billion in 2003. On the global market, more than 90 percent of bivalves are traded in live, fresh, frozen and dried forms, and less than 10 percent as canned products.

In terms of quantity, clams (including cockles and ark shells) and mussels dominate the global fresh and frozen bivalve trade, accounting for around 32 percent and 44 percent, respectively. In terms of value, however, scallops contributed more than 38.4 percent to total bivalves export in 2003, followed by mussels (26 percent), clams (25 percent) and oysters (10 percent).

There is also an active trade in clams and cockles among ASEAN countries, particularly between Malaysia, Thailand and Singapore. Large quantities of cockles and clams from Malaysia are sold to Thailand for reprocessing and re-export and to Singapore for local consumption. Thailand imported 24 867 tonnes of blood cockle worth B 211 million (US$5.3 million) in 2005, almost all from Malaysia. At the same time, Thailand also exported 4 239 tonnes of blood cockle, with the main markets being China, Hong Kong SAR, Japan and China. Meanwhile, Thailand is also the largest supplier of bivalves from the Southeast Asian region, especially canned clams. In 2005, Thailand exported 2 437 tonnes of canned clams worth Baht 267.4 million (US$6.7 million) (Table 13).

TABLE 13
Thailand: exports of canned clams, 2005 (Source: Thai Customs)

Main destinations	Quantity (tonnes)	Volume (Baht million)
Australia	22	2.4
Canada	47	38.3
China	26	2.1
Germany	22	2.0
United Kingdom	49	5.0
Italy	101	8.9
Japan	91	9.1
USA	1 535	142.4
Total (including others)	2 437	267.4

Japan is the largest market for bivalves in Asia, and in fact the country is the largest importer of clams, mainly from neighbouring countries such as China and the Korean Peninsula (Tables 14 and 15). Its imports of clams in 2004 totalled 90 236 tonnes valued at US$147.4 million, and China accounted for 47.2 percent of the supply. Overall, bivalve imports into Japan in 2004 reached 99 087 tonnes worth US$192.3 million, with China taking 44 percent market share followed by the Republic of Korea (35.3 percent) and the Democratic People's Republic of Korea (19.5 percent).

TABLE 14
Japan: imports of live, fresh and frozen bivalves, by main suppliers, 2004 (quantity (Q)=tonnes; volume (V)=US$1 000) (Source: Japan Fish Traders Association, 2004)

Origins	Clam		Oyster		Scallop		Mussel		Total	
	Q	V	Q	V	Q	V	Q	V	Q	V
China	42 608	64 308	133	449	817	3 773	1	3	43 559	68 533
Korea Rep.	11 857	37 691	7 457	38 985	-	-	-	-	19 314	76 676
Korea DPR	321 938	42 992	-	1 731	-	-	-	427	34 938	42 992
New Zealand	3	12	191	-	2	14	115	-	311	2 184
Russia	1 182	1 908	-	-	-	-	-	-	1 182	1 908
Total (including others)	90 236	147 413	7 903	42178	824	3 856	124	475	99 087	192 293

China, the largest market for bivalves, is mainly supplied locally. The country also imports high-value bivalves from other countries to serve the growing demand from the catering sector. The major bivalve suppliers to China are the Democratic People's Republic of Korea, New Zealand, United States of America and Canada (mussels, clams and oysters).

TABLE 15
China: exports of bivalves in 2004 (Source: Chinese Society of Fisheries, 2004)

	Quantity (tonnes)	Value (US$1 000)
Oyster	17 404	23 868
Mussel	17 230	21 241
Scallops	12 681	39 942
Clam	89 628	149 043
Total	136 943	234 094

Other important markets for bivalves in Asia are China, Hong Kong SAR, Taiwan PC and Singapore. In 2004, China, Hong Kong SAR imported almost 19 000 tonnes of bivalves, mainly from mainland China, Japan, the United States of America and Canada, while Taiwan PC, an important market for oysters and scallops, imports mainly from the United States of America, Canada and Japan. In 2004, Singapore imported 8 597 tonnes of bivalves (molluscs) in live, fresh and frozen forms, mainly from Malaysia.

Bivalve trade between developing countries and major markets has not developed well like other seafood products. This is mainly because of food safety issues. Importing countries enforce strict import regulations on bivalves as compared to other seafood that many developing countries are unable to meet.

From Asia, only Japan, the Democratic People's Republic of Korea, Thailand and Viet Nam are currently qualified to export their bivalves to the EU markets. Bivalve-producing countries in Asia such as Indonesia have been attempting to get approval to export their products to the EU but without success.

Singapore, one of the main bivalve markets in the Southeast Asian region, also applied stringent import inspection procedures on bivalve products that are considered to be of high health risk. Imports of bivalve must be accompanied by a health certificate from the competent authority in the country of origin, and samples are collected from every consignment for laboratory tests.

Developing countries need a lot of assistance with the pre- and post-harvest practices for bivalves in order to enable them to meet the requirements of importing countries and to improve product quality and safety. The prospects for developing the bivalve industry in developing countries will depend on their ability to build reliable monitoring and inspection programmes and develop sustainable farming practices.

SEAWEEDS

The seaweed industry is diverse, covering hundreds of species that are found in the northern and southern hemispheres, ranging from coldwater to warmwater species. Seaweeds are classified into three main groups: green, red and brown seaweeds, based on their pigment. Commercially important seaweeds fall under the red and brown groups and account for almost 99 percent of the total harvest, which is derived from 42 countries.

The diversity of the industry is exemplified by the usage of seaweed products in our daily lives. Seaweeds are consumed as food (directly) and extracted into hydrocolloids for various uses in the food, medical, bacteriological, cosmetic, textile, toiletry and chemical industries. From a global seaweed (red, brown and green) production of about 8.65 million tonnes (wet basis) in 2003, about 5.5–6.0 million tonnes was consumed as food and about 1.2–1.5 million tonnes was extracted for hydrocolloids (agar, carrageenan and alginate), while the rest was used for other purposes such as fertilizer and feed.

The edible seaweed industry is concentrated primarily in three countries, namely China, Japan and the Democratic People's Republic of Korea, while the hydrocolloids industry is dominated by a few large companies in Europe and the USA, such as CP Kelco, Danisco, Degussa, FMC Biopolymer and ISP. These companies have a strong foothold in the industry, making it difficult for any newcomer to enter the hydrocolloids market. Meanwhile, seaweed farming is dominated by small-scale farmers who are mostly located in the Asia-Pacific region. Around 88 percent of the total seaweed harvest originates from culture that is almost exclusively carried out in Asia-Pacific countries. Thus more than 60 percent of the global dried seaweed (raw material) exports come from Asia, mainly destined for Europe, the USA and Japan.

In the global market, seaweed products are traded mainly in three different groups: dried raw-material seaweeds; hydrocolloids (agar, alginate and carrageenan) and edible seaweed products (*nori, hijiki, wakame* and *kombu*). The first two groups are widely traded in the international market, while the edible seaweeds are mainly traded regionally in Far Eastern countries (Japan, the Democratic People's Republic of Korea and China). The overall value of the global seaweed trade is estimated to be around US$5 billion, with most value contributed by edible seaweed products.

Exports of dried seaweed have been hovering in the region of 250 000 tonnes per year, with the Philippines, Indonesia and Chile as the main suppliers taking approximately 45 percent of the total export quantity. In 2003, the global dried seaweed exports totalled around 255 000 tonnes valued at US$340 million. The Philippines is the largest supplier of carrageenophyte seaweeds, while Indonesia exports both carrageenophyte and agarophyte (dried *Gracilaria*) seaweeds. Imports of dried seaweed into traditional markets in Europe and the USA have been declining as seaweed producers like Indonesia, the Philippines and Chile have also started developing their own agar and carrageenan processing industries. The market prospects for dried seaweed are good for carrageenophyte, as demand for carrageenan is growing, but the demand for agarophyte and alginophyte seaweeds is facing buyer markets.

Agar

The global trade in agar is active and slowly growing. World exports reached almost 15 000 tonnes valued at US$114.2 million in 2002. Germany, the Democratic People's Republic of Korea, Taiwan PC, Thailand and France were the main agar exporters, while Japan and the USA were the main importers. The imports of agar (kanten) into Japan reached more than 1 633 tonnes valued at US$27.8 million in 2004, deriving mainly from Chile, the Democratic People's Republic of Korea, Morocco and China. The USA market consumes about 2 000 tonnes/year of agar, of which around 64 percent comes from imports. Its imports reached a peak of 1 286 tonnes valued at about US$19 million in 2003, with Chile, Morocco and Spain being the main suppliers. In 2005, the USA imported 1 222 tonnes of agar worth US$19.4 million.

About 90 percent of agar is used in the food industry, while the rest is for bacteriological purposes (Table 16). The market for food-grade agar is predicted to remain stable, while the market for agarose will expand as its biotechnology uses increase.

TABLE 16
Agar markets by product categories in 2001 (Source: FAO, 2003)[1]

Application	Markets by application (tonnes)	Percentage
Food	6 930	91
Bacteriological	700	9
Total	7 630	100

Grade/seaweed	Markets by grade and source (tonnes)	Percentage
Powder/*Gracilaria*	4 100	54
Powder/*Gelidium*	2 305	30
Square/*Gracilaria*	250	3
Strips/*Gracilaria*	275	4
Bacto/*Gelidium*	700	9
Total	7 630	100

[1] The total market has a value of about US$137 million.

Carrageenan

Global carrageenan sales in the food industry are estimated to be around US$320–340 million annually, and the market in Europe is about 15 000 tonnes/year, in the United States of America around 9 000 tonnes/year and in the rest of the world about 25 000 tonnes/year (Table 17). The global market growth for carrageenan is about 4–6 percent annually and is driven by modest growth in food applications, which take about 90 percent of the total carrageenan market.

Imports of carrageenan into the USA increased significantly over the past five years from 5 918 tonnes valued at US$41.6 million in 1999 to 9 658 tonnes valued at US$62 million in 2005. The Philippines is the largest supplier of carrageenan into the United States of America, followed by Denmark, Canada, France and Chile. The use of semi-refined carrageenan (SRC) in the food industry in the United States of America has been increasing since the 1990s, slowly replacing the more costly refined carrageenan.

In 2003, the Philippines exported 42 594 tonnes of seaweeds and seaweed products worth US$80.8 million, free on board (FOB) value, consisting of:

Dried seaweeds	:	31 324 tonnes (US$33.2 million)
Carrageenan	:	10 108 tonnes (US$47.2 million)
Edible seaweeds	:	1 162 tonnes (US$506 000)

Other than the USA and Europe, China, the Democratic People's Republic of Korea and Japan were also the main markets for seaweed products from the Philippines.

In Southeast Asia, the demand for carrageenan is also growing, and the current market size is estimated at around 1 800–2 000 tonnes. Indonesia, Malaysia and Thailand are the main markets, with the consumption of carrageenan estimated to be in the region of 280–300, 200 and 780 tonnes, respectively.

The prospects of the market for carrageenan are positive, driven by good demand from the dairy and meat industries and new methods in the health industry.

TABLE 17
Market size of carrageenan in the food industry (from various sources)

Country	Quantity (tonnes)	Percentage
Europe	15 000	30.3
USA	9 500	19.2
Other markets	25 000	50.5
Total	49 500	100

Alginate

Around 32 000–39 000 tonnes of alginate are produced annually in the world, mainly in the United States of America (10 000–12 000 tonnes), China (8 000–10 000 tonnes), the United Kingdom (6 000–8 000 tonnes), Norway (5 000 tonnes), France (2 000 tonnes) and Japan (1 500–2 000 tonnes). Approximately 67 percent of alginate is of technical grade for industrial purposes (such as textiles), while around 33 percent is used in the food and pharmaceutical industries (Table 18).

Around 12 000 tonnes of alginate was consumed in the United States of America in 2000. The United States of America is also the biggest importer of alginate, its imports totalling 4 179 tonnes worth US$25 million in 2003. Japan also imports a significant amount of alginates, reaching its highest level in 2002 at 1 619 tonnes but dropping to 1 474 tonnes worth ¥ 717 million in 2003.

TABLE 18
Alginate markets by sector, 2001 (Source: H. Porse, CP Kelco ApS, 2002, personal communication; FAO, 2002)

Application	Quantity (tonnes)	Percentage
Food and pharmaceutical	10 000	33
All technical grades	20 000	67
Total	30 000	100

Increasing at around 2–3 percent annually, the growth in the alginate market is predicted to be lower compared to carrageenan. The industry is facing strong competition from Chinese producers who sell cheaper alginate made from *Laminaria*.

Edible seaweeds

The international market for edible seaweeds usually refers to four main product forms, namely *nori* (*Porphyra*), *kombu* (*Laminaria*), *hijikii* (*Hizikia*) and *wakame* (*Undaria*), even though there are other products or species that are also eaten in certain countries. These four edible seaweed products are mostly traded in China, Japan and the Democratic People's Republic of Korea. Japan consumes more than 200 000 tonnes of edible seaweeds (dried forms) annually, with almost 39 percent coming from imports (Table 19). Edible seaweeds enjoy strong demand as a health food product in Japan, its import mainly coming from China (*wakame*) and the Republic of Korea (*hijiki*). Japanese imports of edible seaweed reached their highest point at 76 414 tonnes in 2004. The export of dried *nori* (laver) from the Democratic People's Republic of Korea increased tremendously in 2004, reaching 5 079 tonnes worth US$24 million, mainly to Japan and China. Meanwhile, Chinese exports of dried *Laminaria* totaled 36 906 tonnes valued at US$63 million in 2004, mainly supplying the Japanese market (Table 20).

TABLE 19
Japan: imports of edible seaweeds 1999–2004 (Quantity (Q)=tonnes; Value (V)=¥ million) (Source: Japanese Customs)

	1999		2000		2001	
	Q	V	Q	V	Q	V
Dried *nori*	114	301	196	552	234	835
Hijiki	7 460	5 253	6 088	3 557	6 838	4 243
Wakame	50 096	9 269	40 035	7 173	40 831	7 305
Other seaweed	3 590	1 635	4 221	1 832	4 281	1 921
Total	61 260	16 458	50 541	13 114	52 184	14 303

	2002		2003		2004	
	Q	V	Q	V	Q	V
Dried *nori*	239	802	343	852	365	695
Hijiki	6 088	4 671	6 603	5 220	6 880	4 751
Wakame	42 834	8 348	40 302	7 823	69 757	12 026
Other seaweed	4 434	2 033	4 938	2 276	4 785	2 874
Total	53 594	15 854	52 186	16 171	81 787	20 346

TABLE 20
China: exports/imports of seaweeds and seaweed products in 2004 (Source: Ministry of Agriculture, China, 2005)

	Exports		Imports	
	Quantity (tonnes)	Value (US$ million)	Quantity (tonnes)	Value (US$1 000)
Laminaria	36 906	63 026	1 189	229
Other seaweeds	4 286	19 110	48 540	23 951
Agar	2 704	16 430	125	873
Alginate	12 882	36 561	314	1 889
Total	56 778	135 127	50 168	26 942

Generally, the prospects of edible seaweed in these three countries are not very encouraging, as the markets are fully supplied or even over-supplied for certain products. An aggressive marketing campaign is being launched by edible seaweed producers to introduce these products in other markets such as the United States of America, Europe and Asia.

FINFISH

Grouper, Asian seabass, milkfish, snapper and bastard halibut are among the marine finfish popularly cultured in the region. The industry is diverse in terms of species being cultured with generally low production and/or productivity. Except for milkfish, the large proportion of farmed marine finfish in the region is sold in live form, as it is the only viable way to offset the high production cost. As the supply of marine finfish into the market comes mainly from wild catch that is generally much cheaper, farmed marine finfish like grouper, snapper and to some extent, Asian seabass, cannot compete in wider and processed products markets.

Grouper

In the global market, grouper is usually traded in three different forms: live, fresh/chilled and frozen forms of whole fish; fillets and steak products. Southeast and Far East Asian countries are both the main suppliers and markets for groupers, which are mainly traded in live and whole fresh/chilled forms. Farmed grouper almost exclusively cater to the live fish-trade market in the region. The following are market segments for grouper:

- live grouper: mainly traded in Southeast and Far East Asia, with China, Hong Kong SAR as the largest market and distribution center. Supplies come from both wild and cultured grouper;
- fresh/chilled grouper: Asia is the largest supplier and market, while there is a significant amount of fresh/chilled grouper fillet imported into the United States of America from Mexico and other Latin American countries (wild grouper); and
- frozen grouper: a small amount of frozen grouper is widely traded in the international market with the United States of America, European and Middle Eastern (the Gulf) countries as the main markets (wild grouper).

China, Hong Kong SAR is the main market for live grouper, importing almost 6 000 tonnes of high-value live grouper annually worth more than HK$ 550 million (US$70 million). The exact import figure is believed to be much higher (estimated at 10 000–15 000 tonnes/year), as there is also a large amount of live grouper brought into Hong Kong SAR by registered live fish transport vessels that is mostly not recorded. The main species imported into Hong Kong SAR are coraltrout grouper, green grouper, flowery grouper and other grouper species coming mainly from the Philippines, Indonesia, Thailand, Malaysia and Australia.

Live grouper imported into China, Hong Kong SAR arrive mainly by air or sea, using live fish transport vessels that are usually owned by China, Hong Kong SAR traders. More and more live grouper nowadays are imported by air. After arrival in China, Hong Kong SAR, live grouper is sent to live wholesale markets around the territory and then distributed mainly to restaurants. Kwun Tong wholesale market is the main wholesale market in China, Hong Kong SAR for live grouper.

Other important live grouper markets are China, Thailand, Malaysia, Taiwan PC and Singapore. Except for Singapore, the other markets are largely supplied by local production, with Thailand, Malaysia and Taiwan PC being also the main exporters of live grouper. China is increasingly becoming an important market for live grouper and imports a significant amount from China, Hong Kong SAR. There is however, no official figure as to how much live grouper is imported into the mainland. Singapore also imports live grouper to satisfy local demand, mainly from Malaysia and Indonesia. INFOFISH estimates that around 400–500 tonnes of live grouper are imported annually into Singapore by boat from nearby Sumatra Islands (Batam or Riau), by air from other parts of Indonesia and Sabah and by truck from West Malaysia.

As indicated above, the international market for processed grouper is relatively small compared with that for other marine finfish, mainly because of limited production. FAO recorded that frozen grouper production reached its highest level at 16 144 tonnes in 2002 then declined to 13 504 tonnes in 2003, with Mexico and the Philippines being the two main producers. As many countries do not have separate trade statistics for grouper products, global trade (imports) recorded by FAO are also very small, being less than 4 000 tonnes worth over US$18 million in 2003.

India, Pakistan and Indonesia are the main exporters of frozen grouper, while Mexico is the largest fresh/chilled grouper supplier, sending fish mainly to the USA market. India exported more than 5 000 tonnes of frozen grouper, known as reef cod, to mainly Middle Eastern and European countries, as well as the USA.

In supermarkets in Malaysia, whole chilled grouper is sold in tray packs or in bulk. Flowery grouper is sold at around RM 15.00/kg (US$4/kg) while leopard coral trout is sold at around RM 18–22/kg (US$4.8–5.9/kg) at the retail market. In live seafood restaurants, grouper can fetch a price as high as RM 120/kg (US$32/kg). Demand for grouper is expected to increase in the domestic market as a result of increasing supply from aquaculture and increasing consumers' income.

Asian seabass

International trade in Asian seabass is very limited, the bulk of production being consumed locally or traded among neighbouring countries in Southeast Asia. Thus, the main producers such as Thailand, Indonesia, Malaysia, Singapore and Taiwan PC are also the main markets for this species. The fish is mainly sold in live and whole fresh/chilled forms, while only a small amount is frozen. Unfortunately, there are no separate trade statistics for Asian seabass, as it falls under the general category "seabass", which refers to various species such as European seabass, Japanese seabass, giant seabass, Chilean seabass and also Asian seabass.

Under this category, the global trade of "seabass" is on the rise, the total world exports increasing from 3 601 tonnes in 1994 to 26 058 tonnes in 2003, while the imports reached their highest level at 41 057 tonnes in 2002 before dropping to 38 624 tonnes in 2003. This statistic however, particularly refers to European seabass trade and only a small percentage involves Asian seabass.

The main Asian seabass exporting countries are Australia, Thailand, Malaysia, Taiwan PC and Indonesia. Australia is aggressively promoting its barramundi and targeting the USA and Europe as the main markets. It exports live fingerlings to the USA and the United Kingdom for grow-out and selling the harvest in those markets.

Thailand exports live and fresh/chilled Asian seabass to China, Hong Kong SAR, Malaysia and Singapore. Exports of live marine foodfish from Thailand are recorded at 3 225 tonnes valued at B 367 million (US$9.2 million) in 2004, consisting mainly of grouper, snapper and also Asian seabass. The country also exports a small amount of frozen seabass, around 38 tonnes worth B 3.4 million in 2004, mainly to the United States of America, Japan and Saudi Arabia.

Meanwhile, Taiwan PC exported almost 200 tonnes of frozen seabass in 2003, with the main markets being the United States of America, Canada and Europe. Other supplying countries are Indonesia and Malaysia, which export mainly live seabass to the neighbouring Singapore market.

Singapore imports around 1 000 tonnes of live marine foodfish annually, and it is estimated that around 50 percent is live Asian seabass originating mainly from Malaysia and Indonesia. While the country also imports a large amount of frozen seabass (more than 2 700 tonnes in 2004), it is believed that this is mainly Chilean seabass. Even though the fish is relatively unknown in Japan, China and the Democratic People's Republic of Korea, small amounts of Asian seabass are also imported into these countries mainly from Thailand and Taiwan PC.

There is a small but growing market for Asian seabass in the United States of America and the United Kingdom. In 2004, the United States of America imported 16 090 tonnes of various "seabass" products worth US$132 million. The imports mainly consisted of Chilean seabass (9 580 tonnes) followed by perch (530 tonnes), bass (838 tonnes) and frozen seabass (302 tonnes). To target the growing United States of America market, Australis Aquaculture of Australia has set up Asian seabass growing facilities in Massachusetts whereby the company exports live fingerlings from Australia and grows the fish up to a market size of 600 g over a period of eight months. A similar arrangement has also been established by another Australian company, Aquabella Group Plc, in England. Even though European markets are still dominated by European seabass (*Dicentrarchus labrax*), there is high possibility that Asian seabass can compete in those markets, particularly in northern European countries.

The average value of farmed seabass declined over the years from the highest at US$5.6/kg in 1995 to the lowest at US$3.4/kg in 2002, before moving up again to US$4.2/kg in 2003. Among the main producing countries, Australia and Singapore pay a higher price for Asian seabass, while Taiwan PC produces low-value fish cultured in earthen ponds. In Australia, the massive rise in volume of farmed seabass has driven down the average wholesale price from around $A 10/kg for fresh/chilled gutted fish in 2000 to around $A 7.50–8.50/kg in 2005. Following the trend, fish fillet of Asian seabass (skin-on) also dropped from $A 22/kg in 2000 to around $A 17–18/kg in the Sydney wholesale fish market.

In Asia the price of Asian seabass dropped during the economic crisis in 1998/1999, then recovered in 2000/2001 before dropping again in the last few years. In Hong Kong SAR the live Asian seabass price reached its highest level at around HK$ 50/kg (US$6.5) in 2000/2001, then declined to HK$ 33.3/kg (US$4.3) in 2004. Ex-farm price of Asian seabass in Thailand, however, has been stable since 2001 at around B 90/kg (US$2.3).

The domestic market in Malaysia for Asian seabass is mostly satisfied from local production; only when there is a short supply is the fish also imported from southern Thailand and Indonesia. About 90 percent of the local Asian seabass production is consumed in the local market, mostly in live form through the catering sector. Selling of fresh/chilled Asian seabass is also slowly growing, mainly through supermarkets where sales promotion is regularly conducted.

In the catering sector, Asian seabass is prepared in various styles such as steamed, deep fried, Thai-style, grilled, etc. Consumption is usually high during the festive seasons, such as the Chinese New Year.

The price of Asian seabass in the Malaysian retail market has tended to decline over the years from an average of RM 15.00/kg (US$4/kg) in 1998 to RM 13/kg (US$3.5/kg) in 2005, while in seafood restaurants, Asian seabass is priced (live) at around RM 40.00/kg.

Milkfish

Milkfish is mainly cultured in Indonesia, the Philippines and Taiwan PC and raised largely for local consumption with only a small amount being exported to ethnic markets in the Middle East and North America. In Indonesia and the Philippines, milkfish (called *bandeng* in Indonesia and *bangus* in the Philippines) is a very domestic product. The Philippines produced 246 505 tonnes of farmed milkfish in 2003, mainly for local markets with a small amount exported to North America and the Middle East.

In 2004 Taiwan PC exported 8 166 tonnes of milkfish worth NT$ 455 million, the bulk in frozen form, mainly to Saudi Arabia, the United States of America, Canada, Australia and Southeast Asian countries.

Indonesia produced around 226 000 tonnes of milkfish, largely for local consumption in Java and the South Sulawesi Islands where it is a popular foodfish. Milkfish is also used as bait in tuna long lining, which is widely practiced in Indonesia.

THE CHALLENGES AND TRADE ISSUES

In recent years, trade of seafood products in the international market has been very challenging, with a lot of controversies and issues affecting the trade flows. Among the challenges and issues related to marketing of marine aquaculture products are:

(a) Declining prices: Prices of selected farmed products such as shrimp (*Penaeus monodon* and *Litopenaeus vannamei*) have tended to decline over the years, especially for traditional products such as block frozen headless shrimp. For example, the price of *P. monodon* headless from Indonesia to Japan (C&F price) for size 16/20 has declined from the higher level at around US$15.00–17.00/kg during the period of 1995–2000 to around US$10.00–12.00 for the past few years. Similarly, there are signs of softening in the price of *L. vannamei* shrimp in Europe as a result of cheaper supply from China. In the local market, such as in Malaysia, shrimp is also becoming cheaper as a result of the abundant supply from aquaculture. Due to strong competition from other species, seabass price has also been declining. The declining prices of farmed products are not exclusively suffered by tropical species but also hit coldwater species such as salmon, and European seabass and seabream. Reportedly the price of high-grade bluefin tuna in Japan declined sharply from around ¥ 5 000/kg ten years ago to currently around ¥ 2 000/kg because of the sharp increase in farmed bluefin tuna supplies.

(b) Strong competition from other products: The fast growing regional market has attracted seafood products from all over the world. Coldwater species such assalmon, cod, pollack, etc. can now be found in almost every supermarket in the region. Nile perch fillet from Lake Victoria and tra and basa fillet from Viet Nam are flooding the regional markets, giving strong competition to locally produced marine finfish such as Asian seabass, snapper and grouper.

(c) Limited marketing options for farmed marine finfish: Due to high production costs, farmed grouper, snapper and to some extent Asian seabass are only viable to be marketed in live form. At the moment selling them as processed products is not economically viable.

(d) Trade issues: The anti-dumping duty enforced by the United States of America on shrimp from six countries has had significant effect on the shrimp industry and the market in the region. In addition to the economic and financial losses suffered by the industry in the affected countries (India, Thailand, China and Viet Nam), many shrimp processors and producers are now giving more attention to the local and regional markets. As a result, competition in the local and regional markets is increasing, resulting in decreasing prices.

This trend has also been exploited by a highly competitive retail sector that often uses shrimp as a promotional item. While this is a good thing for consumers, who can now buy shrimp at cheaper prices, producers and farmers are being squeezed out of their profit margin.

The reported imports of shrimp from the affected countries to non-affected countries such as Indonesia and Malaysia has also raised concern among the industry, resulting in the Indonesian authorities banning the importation of shrimp.

(e) Environmental issues: The environmental issues affecting the marine aquaculture sector are well known, but recently these issues have increasingly been linked to trade and many feel they are also being used as trade barriers. "Green" groups are now targeting multinational chain retailers and the catering sector to influence them to buy and sell seafood from eco-friendly sources.

(f) Safety issues: The uncontrolled use of certain antibiotics has also affected the trade of marine farmed products, especially shrimp. While the issue of residues of chloramphenicol and nitrofurans in shrimp is more or less resolved, malachite green found in fish products has become a new issue.

(g) Traceability and country of origin labelling: While the industry players in this region, especially the big seafood processors and exporters, are fully aware and possibly capable of fulfilling traceability and country of origin labelling requirements, the implementation by small players, especially at the farmer's level, would be somewhat difficult and possibly complicated. Due to the small and scattered nature of the aquaculture industry in the region, implementing traceability requirements will require extra work and expenditure.

(h) Rules of origin: Rules of origin enforced by importing countries such as the EU's generalized scheme of tariff preferences (GSP) scheme can also have an effect on regional trade. For example, seafood products from ASEAN countries (except those from Myanmar, for political reasons) enjoy preference tariff under the EU-GSP scheme. As a result, some packers in other ASEAN countries are having problems with the importation of raw materials from Myanmar if the final product is to be exported to the EU.

FUTURE PROSPECTS

The regional seafood market and trade in the region is expected to expand further, largely due to economic development, increase in supply from the aquaculture sector, growing retail and catering sectors and changing lifestyles that favour health foods. Demand for shrimp is predicted to grow faster than that for other farmed marine products. The growth will be driven by an increasing supply and by sales in the retail and catering sectors.

For marine finfish aquaculture, the market expansion will depend on the development of production technology and reduction in production cost. Otherwise, the market for certain farmed finfish species such as grouper and snapper will be limited to the live market segment.

In this region, the high level of bivalve consumption is achieved through the catering sector, such as hotels and restaurants, especially for high-value species such as mussel, oyster and scallop. With the catering sector growing as a result of increasing consumer income, changing lifestyles and a booming tourism industry, the demand for bivalves in this region is expected to grow. Aquaculture will play a major role in meeting the growing demand. Competition is also expected to come from imported products such as green mussels from New Zealand.

The prospects for seaweed products are generally good for hydrocolloid seaweeds, especially carrageenan. The international market for carrageenan is expected to grow by 4–6 percent per year as a result of the growing food industry. The demand for SRC, which is produced in a huge volume in the region, is also growing faster and replacing refined carrageenan.

For edible seaweed, however, the market is stagnant, and the current production level can fulfil the demand. With the increasing popularity of Japanese and Korean seafood restaurants in the region, demand for certain edible seaweeds may grow gradually in Southeast Asian countries.

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Regional review on livelihood opportunities related to mariculture development

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INTRODUCTION

The United Nations Millennium Development Goals call for a reduction in the proportion of people living on less than US$1 per day (economic or income poverty) to half the 1990 levels by the year 2015. Global poverty is considered one of the major causes of food insecurity, and poverty eradication is seen as essential in improving access to food (Tacon, 2000). It is expected that global poverty rates will fall to 13 percent, meaning that the goals will be met and there will be 360 million less people living in abject poverty. However, progress in eradicating hunger has been slower, with the situation actually worsening in regions such as South Asia.

This paper draws on secondary literature, media reports and country reviews from NACA/STREAM Communications Hub Managers in India, Indonesia, Myanmar, Pakistan and the Philippines. It examines the role mariculture could play in reducing poverty and providing alternative livelihood opportunities for people living in coastal areas. This includes a review of the current status of coastal poverty, coastal livelihoods and vulnerabilities within the Asia-Pacific region and the experiences and examples of sustainable economic development through mariculture. This review then identifies key follow-up actions and recommends strategies for future pro-poor mariculture development.

FOOD SECURITY AND THE ROLE OF FISHERIES IN ASIA-PACIFIC

Fish and aquatic products contribute massively towards food security and currently supply around 7 percent of the global food supply (Haylor *et al.*, 2003). As fish is generally more affordable to poorer members of society, a greater amount of this protein source is consumed on a per capita basis than any other type of animal protein (Tacon, 2000). As a result, fish and aquatic products are the primary source of animal protein for over one-sixth of the global population. In the Asia-Pacific region, fish makes up more than 50 percent of animal protein intake (Haylor 2004) with the People's Republic of China dominating consumption (36 percent); India and Southeast Asia account for another 17 percent (Delgado *et al.*, 2003).

The demand for fish is also increasing, not only because of an increasing population but also due to a greater awareness of the importance of fish in the diet (Delgado *et al.* 2003; IMM, CFDO and CBNRM LI, 2005). There is consensus that traditional sources of fish such as global capture fisheries have peaked (FAO, 2002), and the future of wild-caught fishery production appears to be uncertain. Currently 47 percent of fish stocks are described as being fully exploited or close to their maximum sustainable limits (Delgado *et al.*, 2003; FAO, 2002; IMM, CFDO and CBNRM LI, 2005). Others are in a state of decline or are completely exhausted. Recent studies based on trawl surveys in eight Asia-Pacific countries by the WorldFish Centre indicate that the situation may be far more serious than these figures suggest, and that substantial degradation and over-fishing have occurred. According to the surveys, coastal stocks have declined by as much as 40 percent in five years (Silvestre *et al.*, 2003). Consequently, it is believed that the amount of fish available for the region's fishers is now only a fraction of what was available before the industrialization of fishing (Sugiyama, Staples and Funge-Smith, 2004).

Coastal populations that once almost entirely depended on inland or coastal capture sources of fish have seen their resources decline, and once cheap and plentiful wild fish have become less available and less affordable (Yap *et al.*, 2006). In some locations around coral reefs, fishers are turning to lucrative yet destructive practices such as the use of explosives (blast fishing) and cyanide to stun and capture fish (Burke, Selig and Spalding, 2002). There are also numerous reports of conflicts over diminished fishery resources and increased illegal fishing activities as fishers from one community, region or country encroach into the territories of their neighbours (Bulcock and Savage, 2005).

THE INTERNATIONAL FISHERIES TRADE

Despite the apparent crisis in global fisheries, the international trade in aquatic products has grown significantly over the last few decades, supported by improvements in technology, transport, communications and increased demand (FAO, 2003a). Consequently, fisheries export values have increased from US$15 billion in 1980 to US$56 billion in 2001 (Macfadyen *et al.*, 2003), and a large percentage of fisheries and aquaculture production now enters international marketing channels and chains, with more than 37 percent exported in 2000 in various forms. Once again, developing countries, predominately in Asia, play a major role in this trade (Macfadyen, Phillips and Haylor, 2005), and fisheries and aquaculture are therefore significant contributors towards national economies across the region, particularly Small Island Developing States (SIDS) (Table 1) (Sugiyama, Staples and Funge-Smith, 2004).

TABLE 1
Contribution of capture fisheries and aquaculture to gross domestic product (GDP). (Source: Sugiyama, Staples and Funge-Smith, 2004)

Production value as % of GDP			
Capture fisheries		Aquaculture	
Kiribati	33.549	Lao PDR	5.775
Marshall Islands	28.378	Viet Nam	3.497
Maldives	17.294	Bangladesh	2.688
Cambodia	10.030	Philippines	2.633
Solomon Islands	7.787	China	2.618
Federated States of Micronesia	6.603	Thailand	2.071
Samoa	4.239	Indonesia	1.662
Viet Nam	3.702	Cambodia	0.893
Papua New Guinea	3.306	Kiribati	0.752
Vanuatu	3.294	India	0.540
Tonga	2.865	Sri Lanka	0.468
Indonesia	2.350	Malaysia	0.366
Philippines	2.184	Nepal	0.345
Fiji Islands	2.046	Taiwan PC	0.324
Thailand	2.044	New Zealand	0.189

COASTAL COMMUNITIES

Poverty status

It is estimated that about 1.9 percent of the world's population derive their livelihoods from fishing and fishing-related activities, in both inland and marine environments (FAO, 2004), with the vast majority found in Asia (Table 2) (FAO, 2002). The majority of these fishers are small-scale, artisanal, coastal operators and among the poorest in society, depending on open access to fisheries resources as a last resort (IFAD, 2002). Income generated by fisheries is generally lower than that from other sectors, and within the sector itself small-scale fishers earn the lowest incomes (Silvestre *et al.* 2003). Within Asia, poverty in coastal areas is a defining characteristic of countries such as Bangladesh, India, Indonesia, Myanmar, Pakistan, Philippines and Viet Nam (Table 3) (IFAD, 2002). The extent of poverty in coastal communities is difficult to measure (FAO, 2002), and while there have been many studies on poverty in farming and urban areas, there have been few that have concentrated on the fisheries sector. Most studies that have been conducted focused on an assessment of income rather than more broad-based approaches to the livelihoods of fishers themselves (FAO, 2002). Reviewing literature on the subject, Macfadyen and Corcoran (2002) found that there had been few studies and analyses on the extent, nature, causes and dynamics of poverty in fishing communities and limited study on the extent to which the fisheries sector and its various associated activities (e.g. fish processing, marketing and distribution) contribute to poverty alleviation and food security.

TABLE 2
Poverty estimates in small-scale fisher communities in Asia (Source: FAO, 2002)

Category	Estimate for Asia
% of population on <US$1 per day	25.6%
Inland fisheries	514 023
Marine coastal	95 837
Marine other	551 133
Unspecified	3 660 428
Total	4 821 421
Number of related income-poor jobs	14 464 262
Total number of income-poor	19 285 683

TABLE 3
Poverty status in country reviews

Country	Poverty Status
India	The vast majority of India's poor people live in rural areas (Mohan, Sathiadhas and Gopakumar, 2006). Rural poverty is estimated at 42.7 percent, with 43.3 percent of India's rural poor people belonging to Scheduled Tribes and Castes (Mukherjee, 2006).
Indonesia	Over 70 percent of fishers are poor. In some areas it may be over 80 percent. Poverty levels in coastal communities are generally considered to be around 80 percent of the population (Suspita, 2006). In total, there are 36 million poor people in Indonesia (Jaya, 2006).
Myanmar	Of the population of 54 million, 22.9 percent are described as income-poor (Maung Soe, 2006).
Pakistan	No poverty profile dealing with the specific aspects of poverty in coastal communities of Pakistan has been developed (Wattoo, 2006).
Philippines	Of the Philippines' 88 million people, 22.78 percent are living below the annual poverty threshold of US$220.64. The three regions with the highest percentage of income-poor families are found in Mindanao (Gonzales, 2006).
Viet Nam	Income poverty has been reduced by 50 percent between 1991 and 2000. However, the poorest communities are still those reliant on coastal fisheries (Nguyen, 2006).

Livelihoods[1]

The fisheries sector provides employment to a large workforce, although they represent only a small proportion of the region's population. Asia has a total of some 25 million fishers and fish farmers, which is more than double the number in the 1970s, and 80 percent of the world's total (IFAD, 2002). In South and Southeast Asia, 10.4 million people work as full-time or part-time fishers, with about 8.6 million employed in marine fisheries and the remaining 1.7 million employed in inland fisheries (IFAD, 2002). Coastal fisheries provide employment to two million people in Indonesia, 1.55 million in Bangladesh and 1.4 million in Viet Nam (Silvestre *et al.*, 2003). The types of livelihoods are complex and vary tremendously (IMM, CFDO and CBNRM LI, 2005), from full-time small-scale operators to those involved in seasonal and migratory positions in the processing and marketing industries (Box 1).

[1] A livelihood is defined as comprising the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain the natural resource base (DFID, 1999).

Where the diversity of systems and species remains high, such as in Cambodia, aquatic resources offer considerable opportunities (IMM, CFDO and CBNRM LI, 2005) to coastal people to "diversify their livelihoods" to suit changing needs. Aquatic resources provide an important social and economic safety net (IMM, CFDO and CBNRM LI, 2005), particularly for poorer members of society. Estimated incomes (Table 4) vary considerably with coastal communities.

BOX 1

Coastal livelihoods in Pakistan

The dominant livelihoods in coastal areas of Pakistan can be categorized as follows: fishing and related activities that employ an estimated 90 percent of the population; agriculture and forestry, in which 8 percent of the population is involved; and the services sector, which employs 2 percent of the population. The fisheries sector employs the majority of the population of coastal villages (*talukas*) in a number of ways – as fishermen, boat owners, helpers (*khalasis*), boat captains (*nakho*), workers in ice factories, transporters and drivers of fish-carrier vehicles.

(Source: IUCN Pakistan, 2003; Wattoo, 2006)

TABLE 4

Estimated income levels in coastal communities of Olango and Batasan Islands, Philippines (Source: Gonzales and Savaris, 2005)

Livelihood	Estimated income (US$/month)
Ornamental fish collector	9–233
Odd job worker	18
Packers of ornamental fish	3.6–7.2
Fishers	36–144
Shell gleaners	2.7–4.5
Vendors of seafood products	43–50
Store owners	144
Carpentry work	54 (2.7 per day)

Country reviews collated in this study from India, Indonesia, Myanmar, Pakistan, the Philippines and Viet Nam are widely diverse but identify distinct characteristics of coastal livelihoods across the region, particularly of poorer members of society. These include (i) a tendency towards reliance on natural "keystone resources" (Box 2), (ii) a diversified livelihoods approach and (iii) shifting, often seasonal, balances in resource use and the division of labour (Haylor *et al.*, 2003; Gonzales, 2006; IMM, CFDO and CBNRM LI, 2005; Mohan, Sathiadhas and Gopakumar, 2006; Nguyen, 2006; Suspita, 2006; Wattoo, 2006; Whittingham, Campbell and Townsley, 2003).

BOX 2

Role of coral reefs in the livelihoods of coastal communities in Asia-Pacific

Around half a billion people live within 100 km of a coral reef, and many of these are dependent on fishery-based livelihoods that are in turn dependent on coral reefs. The diversity and productivity of coral reef resources in these areas also act as sinks for such people, providing a range of livelihoods strategies (Whittingham, Campbell and Townsley, 2003). Therefore coral reefs are vital to the livelihoods of millions worldwide and particularly within Southeast Asia. In some areas, for instance the coastal regions of major archipelagos including Indonesia and the Philippines, and small Pacific island states, this dependence is extremely high (Burke, Selig and Spalding, 2002; Whittingham, Campbell and Townsley, 2003). Reefs are known to act as a "key-stone resource" i.e. one ensuring that people just manage to escape poverty. They are described as "interstitial poor" in that they are often overlooked in coastal development projects, many groups do not have the resources to undertake alternative development options, and they are extremely vulnerable to any decline in reef condition.

(Source: Whittingham, Campbell and Townsley, 2003)

Associated post-fishery activities such as processing and the trading of aquatic products also generate employment and income to millions of people around the world (Macfadyen, Phillips and Haylor, 2005). At the local level, wealth generated through trade can make significant contributions to rural development through income and employment multiplier effects. At the household level, the catching or harvesting of fish and associated post-harvest activities such as processing and trading generate livelihoods, employment and income (Box 3) (Macfadyen *et al.*, 2003; Nguyen, 2006).

BOX 3

Fishery and aquaculture-based livelihoods in Viet Nam

It is estimated that there are more than three million people in Viet Nam who depend either directly or indirectly on fisheries for their income. Ninety percent of all fishers are artisanal and small-scale and most of them are poor. The fisheries sector is a significant source of income, not only in the case of full-time fishers, but also for households that combine fishing as a component of their wider livelihood strategies. The biggest source of fishing and aquaculture income is generated from the Mekong Delta, where between 60 and 70 percent of households are involved in aquaculture. In this area, the average income from aquaculture ranges from US$36–79 per month. Almost all aquaculture producers are small-scale in their activities and belong to private households, although some cooperatives have recently been established. The aquaculture sector provides employment for 668 000 workers and shrimp aquaculture accounts for more than half of this.

(Source: Nguyen, 2006; Macfadyen et al.*, 2003; Tuan, 2003)*

Coastal livelihood trends

Throughout Asia, coastal populations are increasing due to a combination of local population growth and migration (Haylor *et al.*, 2003). There has also been an increase in overall fishery production and trade over the last few decades and a corresponding increase in employment in the fishery and aquaculture sector. In 2000 an estimated 38 million people were directly engaged in fishing and fish farming as a full-time, or more commonly part-time, occupation, compared with 28 million a decade earlier (Table 5) (FAO, 2002; IMM, CFDO and CBNRM LI, 2005). Despite the peaking of capture production, wild-caught fisheries are still considered a profitable livelihood, particularly for the owners of commercial fishing vessels (Silvestre *et al.*, 2003), and the number of fishers has been growing at an average rate of 2.2 percent per year since 1990 (FAO, 2002). The number of aquaculture workers has also increased by an average of 7 percent, with growth particularly marked in Asia (FAO, 2002). However, it is suspected that these positive figures disguise the plight of small-scale subsistence fishermen throughout the region. In general, it is thought that while owners of commercial vessels can and do earn large sums of money, small-scale fishers barely make a living (Silvestre *et al.*, 2003). Across the region, small-scale fishers are believed to be increasingly marginalized by a growing number of commercial fishing boats that often fish over quota and use illegal fishing practices; there is increasing disparity within the fisheries sector (Mohan, Sathiadhas and Gopakumar, 2006).

TABLE 5
Number of fishers and farmers (x1 000) by region (Source: FAO, 2002)

Continent	1990	1995	2000	2001	2002
Africa	1 917	2 238	2 585	2 640	2 615
North and Central America	767	770	751	765	762
South America	769	814	784	760	770
Asia	23 654	28 552	30 770	31 493	32 821
Europe	654	864	821	796	746
Oceania	74	76	86	80	81
World	27 835	33 314	35 797	36 534	37 795
Of which fish farmers					
Africa	-	105	112	115	111
North and Central America	53	74	74	69	65
South America	16	88	92	92	93
Asia	3 698	6 003	8 503	8 720	9 502
Europe	11	36	37	39	39
Oceania	neg	1	5	5	5
World	3 778	6 307	8 823	9 040	9 815

Vulnerability

Although communities are often relatively cash rich – in that they are able to sell their products more frequently and consistently than can land-based farmers (FAO, 2002) – they often remain vulnerable to sudden and seasonal variations in earnings (FAO, 2002), along with many other factors, the outcome of which may be income-poverty (FAO, 2002). These include climatic and severe weather events, storms, seasonally adverse weather conditions and natural disasters, e.g. exceptionally in 2004 there was a devastating tsunami in the Indian Ocean (Box 4) (CONSRN, 2005; Gonzales, 2006; Suspita, 2006). Because of its scale and severity, the tsunami focused the world's attention on the plight of poor coastal communities. They are vulnerable to economic factors such as debt, fluctuations in market price and access to markets, health issues such as ill health and accidents leading to a loss of income, and environmental factors such as pollution, over-exploitation of natural resources and destructive fishery practices (FAO, 2002; Gonzales, 2006; Maung Soe, 2006; Mohan, Sathiadhas and Gopakumar, 2006;

Silvestre *et al.*, 2003; Suspita, 2006; Wattoo, 2006; Nguyen, 2006). Poor coastal communities are also under the increasing threat of marginalization in the face of increasingly competitive commercial fishing enterprises (IFAD, 2002). Unfortunately, it appears that the vulnerability of coastal communities is increasing (FAO, 2002). This often forces poor individuals to develop short-term survival strategies such as destructive and over-fishing practices that further increase a community's vulnerability (IFAD, 2002; Wattoo, 2006).

BOX 4

The Indian Ocean tsunami

The Indian Ocean tsunami event of 26 December 2004 demonstrated vividly the vulnerability of coastal communities throughout Asia-Pacific and eastern Africa. Estimates put the human cost of the tsunami at just under 300 000 people killed and a negative impact on the livelihoods of around five million people, particularly in Indonesia and its region of Aceh, and in Sri Lanka. The majority of those affected followed agricultural or fisheries-based livelihoods or were employed in associated enterprises. The degree of damage to lives and property varied within and between countries and communities, with some suffering a complete loss of villages, homes, fishing and aquaculture infrastructure (including port and post-harvest facilities), fishing vessels and gear, aquaculture facilities (including ponds, cages, hatcheries and broodstock), markets and other livelihoods assets (CONSRN, 2005).

In Sri Lanka at least one million people were directly affected, with the worst affected areas being the underdeveloped coastal regions in northeast, east, south and southwest coastal areas of the country. The majority of job losses were in the service sector, followed by fishing, agriculture and industry. Up to 100 000 fishermen are now unemployed and 18 500 fishing vessels have been lost or badly damaged (http://www. ilo.org).

In Aceh Province, Indonesia, aquaculture is a significant livelihood for many coastal dwellers. The tsunami destroyed or severely damaged more than 50 percent of all brackishwater aquaculture ponds (*tambaks*), the main farming systems for milkfish (*Chanos chanos*) and shrimp (*Penaeus monodon* and other species). Aquaculture production has effectively stopped in the major farming areas of the east coast. As the economy in these areas is heavily dependent on aquaculture and fisheries, farmers and labourers are also faced with few opportunities for alternative employment.

(Source: Suspita, 2006)

The extent to which international trade can benefit poor rural and coastal communities is also vulnerable to key factors and trends. These include changing demand for different types of fish products, increasing moves towards Corporate Social Responsibility (CSR) certification and traceability, increasingly strict health and hygiene regulations, and requirements of the regulatory framework for international trade, including trade barriers and subsidies. All these factors, while offering opportunities for poor people, also present certain risks in terms of their exclusion from the market chain and the benefits of increased trade (Macfadyen, Phillips and Haylor, 2005).

THE CURRENT STATUS OF AQUACULTURE AND MARICULTURE IN ASIA-PACIFIC

Since yields from capture fisheries are not expected to increase, an emphasis is being placed on the aquaculture sector's ability to provide increasing quantities of aquatic products. Production from inland aquaculture and marine and brackishwater-based aquaculture (mariculture) are both increasing (FAO, 2002, 2003a, 2004; Sugiyama and Funge-Smith, 2003; Sugiyama, Staples and Funge-Smith, 2004) and now account for 30 percent of total aquatic production (Delgado *et al.*, 2003). Low-income food deficit countries (LIFDCs) lead the way in this growth, dominated by China PC and other Asian countries (FAO 2003a). As a result, the Asia-Pacific region (including China PC) is the largest contributor to world aquaculture, producing 46.9 million tonnes or 91 percent of total global aquaculture by volume and 82 percent by value (Yap *et al.*, 2006). Aquaculture production within the region is diverse, but in terms of volume it is still dominated by freshwater fish production (39 percent), followed by aquatic plants (29 percent), crustaceans (13 percent), marine and diadromous fish (13 percent) and molluscs (7 percent). In terms of value, crustaceans such as the tiger prawn (*Penaeus monodon*) dominate, accounting for 49 percent of production, followed by freshwater fish (35 percent) (Yap *et al.*, 2006).

The potential role of mariculture in poverty reduction and food security

The shifting emphasis in production from fishing to aquaculture and mariculture, and the growth in the international trade in aquatic products are often believed to offer the potential to contribute towards poverty reduction and food security through the creation of jobs and alternative sources of food. They may also provide a way to encourage those involved in destructive fishing practices to adopt a more sustainable form of livelihood (Gonzales, 2006; Haylor *et al.*, 2003; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006). From the country reviews undertaken for this study, mariculture practices considered potentially "pro-poor" were identified in every country except Pakistan, which currently has an extremely limited and mostly experimental mariculture industry focusing on shrimp (Wattoo, 2006) (Table 6).

TABLE 6
Mariculture practices identified in country reviews (Source: Gonzales, 2006; Maung Soe, 2006; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006)

Country	Mariculture activity
India	Mud crab fattening
	Shellfish culture
	Shrimp processing
Indonesia	Traditional milkfish production in *tambaks* (ponds)
	Traditional prawn culture
	Mud crab fattening
	Shellfish culture
	Sea cucumber
	Seaweed culture
	Shrimp and finfish hatcheries
Myanmar	Traditional shrimp farming
	Mud crab fattening
	Marine finfish seed supply
Philippines	Shellfish farming
	Milkfish production in cages and pens
	Backyard grouper production in cages
	Seaweed culture
Viet Nam	Integrated shrimp-mangrove farms
	Marine finfish culture and fattening in cages
	Lobster culture and fattening in cages
	Shrimp processing
	Shrimp and finfish hatcheries

Livelihoods from mariculture include:

- fry collection and supply for milkfish, grouper and shrimp; small-scale trading and middlemen for mariculture products and inputs;
- production of milkfish, groupers, mud crabs, and lobsters in cages and pens, seaweed production (including family-owned and operated seaweed farms), mussel and oyster production;
- waged labour for hatcheries such as feeders and tank cleaners;
- waged labour in production, caretaking of fish cages and pens, and shrimp ponds; seasonally hired pond and cage work and hired labour for cage construction and fish harvesting; and
- waged labour (cleaning and labouring) in processing facilities such as shrimp and other seafood product packing and processing facilities (Gonzales, 2006; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006; Wattoo, 2006) (Appendix I).

Examples of pro-poor mariculture in Asia-Pacific

Finfish farming

Throughout the region, groupers (*Epinephelus* sp.) and other marine finfish such as milkfish (*Chanos chanos*) are typically farmed in ponds or cages (which can sometimes offer the opportunity for landless individuals and fishers to become involved in mariculture activities). Marine finfish culture comprises an increasingly well-known set of technologies. However, the fattening of wild-caught fish and juveniles needs to be conducted within the context of sustainable management of the capture fishery. Nursing fish seed, production and processing may provide employment or small-scale business opportunities for poor people in coastal areas. Table 7 illustrates the opportunities that small-scale grouper culture is thought to possess, as perceived by poor coastal villagers in Khanh Hoa Province, Viet Nam.

Successful examples of where small-scale finfish culture has benefited poor coastal communities exist in Tubigon, Bohol, Philippines, where the small-scale cage culture of grouper was introduced by local government as an alternative to destructive fishing practices. There are now 141 grouper farmers organized into nine groups throughout several villages (Gonzales, 2006). Another Philippine example is the so-called "backyard type of grouper culture" such as in Day-asan, Surigao City. Here each farmer owns between two and four 3x3 m cages, each stocked with around 100 fish. Where these are fed wild-caught fish as feed and cultured for a period of five to six months, there are question marks over sustainability. Production costs are estimated at P 200 (US$3.88) per kg, with farmers claiming it is more profitable than more familiar livelihoods such as backyard pig production. The average selling price ranges from P 400–1 000 per kg (US$7.77–19.42), depending on the type of grouper and season (Gonzales, 2006).

However, there are also many potential constraints to finfish culture and its suitability as an alternative livelihood for poor fishers. These include the high-technology, capital-intensive and long-term payback characteristics of finfish farming, and the difficulty of uptake of mariculture, including breaking the cycle of debt among poor fishers and persuading people to change vocations (Haylor *et al.*, 2003). In the Ilocos region of the Philippines, where the milkfish industry is concentrated, the production costs per cage are reported as US$23 504, although a profit of just over US$3 000 is expected (Gonzales, 2006). Such high costs have deterred small-scale fishers from investing in these technologies and the cages are owned by wealthier individuals (Gonzales, 2006). There are also environmental considerations, for example, the proliferation of fishpens and fishcages in shallow and narrow waterbodies has resulted in occasional but severe fish kills (Gonzales, 2006; Rosario, 2006). In Indonesia, the *tambak* culture of finfish is also thought to have led to environmental degradation in some instances (Suspita, 2006).

TABLE 7
The potential of small-scale cage aquaculture to improve livelihoods (Source: Hambrey, Tuan and Thoung, 2001)

Problem and constraint as identified by villagers	Rating	Comment
Low income	high	Cage aquaculture generates high returns compared with alternative activities.
Dense population and lack of land	high	There are many available sites for cage aquaculture in Khan Hoa.
Poor and/or impoverished soils	high	-
Shortage of freshwater	neutral	This is an infrastructure issue.
Forest fires and mangrove destruction	medium	Cage aquaculture development could take the pressure off mangrove systems.
Shrimp disease	medium	Cage culture offers an alternative.
Flooding	high	Cage aquaculture is not vulnerable to flooding.
Erosion	neutral	-
Overexploitation of fisheries	low-medium	Development of cage aquaculture could take the pressure off inshore fisheries – although feed and seed supply are a problem in this regard.
Use of destructive fishing gear (e.g. cyanide, electric fishing push-nets)	low-medium	Unsustainable with efforts impacted by punitive measures as well as alternative livelihoods, which could include cage culture (see Philippines example below).
Degradation of coral reef	medium	Fishing for seed does not involve habitat destruction.
Pollution from shrimp farming, shrimp hatcheries and animal husbandry	neutral	Cage aquaculture may cause similar pollution problems, although far less concentrated.
Poor roads	neutral	This is an infrastructure issue.
Access to markets	high	Cage aquaculture generates high-value products and marketing channels are well developed.

Crab and lobster fattening

Mangrove crab production or the fattening of mangrove crabs (*Scylla* spp.) in earthen ponds and simple cages has a long history in the region. The crabs are attractive for the growing export market as they can be easily packed and shipped live (Yap *et al.*, 2006). Small but successful mangrove crab industries exist throughout Asia-Pacific, for instance in Indonesia where hatchery technology is now available (Suspita, 2006) and Myanmar where fattening is common along the coasts of Rakhine, Ayeyarwady and Tanintharyi and is being extended by research institutes (Maung Soe, 2006). Mangrove crab culture also has the advantage of being able to integrate within mangrove systems and therefore is often seen as a way to promote sustainable forms of aquaculture to benefit income-poor groups.

Other crustacean species under culture include lobsters, which are fattened and again rely on wild-caught seed. Species such as the spiny lobster (*Panulirus* sp.) can fetch US$25 per kg (Yap *et al.*, 2006) and are cultured throughout the region. Viet Nam in particular is a major producer, with 17 000 lobster cages recorded along the south central coast alone (Nguyen, 2006). However, operating costs are high, for example lobster farming in Nha Trang Bay, Viet Nam has operating costs of almost US$1 750 for seed and feed (IUCN, 2003), which is a deterrent to uptake by poorer members of communities who often have extremely limited access to credit. However, within Viet Nam, the pro-poor culture of lobster, finfish and a range of aquatic species is being investigated under the SUMA (Support to Marine and Brackishwater Aquaculture) component of the Danish International Development Agency (DANIDA)-funded FSPS (Fisheries Sector Programme Support) project. SUMA has already introduced sustainable breeding and culture technologies adapted to Vietnamese conditions for a range of species including top shell (*Trochus niloticus*), abalone (*Haliotis asinine*), mud crab (*Scylla serrata*), swimming crab (*Portunus pelagicus*), hard clam (*Meretrix meretrix*), sea cucumber (*Holothuria scabra*) and oyster clam (*Lutralia philippinarum*). Demonstrations have also been carried out in Quang Ninh, Nam Dinh, Nghe An and Ha Tinh provinces for species such as shrimp, seabass, rabbitfish, abalone, sea cucumber, green mussels and grouper in ponds and cages.

Extensive seaweed and shellfish production

In contrast to these semi-intensive systems is the extensive or traditional culture of seaweed and shellfish. Due mainly to their low input requirement and extensive nature, these are regarded as environmentally sustainable (Suspita, 2006) and another potential "entry point" for the inclusion of poor coastal communities in mariculture activities. Seaweed is thought to be a particularly promising culture method and is the focus of government promotional campaigns in Indonesia and the Philippines (Suspita, 2006; Gonzales, 2006). It is of interest to other governments in the region, including Cambodia. Indonesia has a rapidly growing seaweed industry and the Directorate General of Aquaculture (DGA) views seaweed production as an opportunity to reduce poverty in areas such as West Nusa Tenggara, Bali and Lampung. Seaweed technology is considered as relatively easy to implement, with a short lifecycle and an existing market, and the DGA is currently promoting seaweed culture through collaboration with local banks that provide the capital needed for start-up operations (Box 5). It also has the potential to involve various household members including women, which makes seaweed culture particularly attractive as a poverty reduction strategy (Suspita, 2006). Such approaches have resulted in farmers reporting incomes of around US$300–500 per month. Although culture itself may be less capital intensive, depending on the seaweed type and the production objective, processing may be a particular issue, especially facilities or processes for drying prior to transport and particularly in remote areas.

BOX 5

Seaweed culture in Sembilangan Village, Java, Indonesia

Sembilangan Village is situated in the northern part of Bekasi District, Java, Indonesia, where villagers earn a living from the sea and through brackishwater pond culture of milkfish and shrimp. Environmental degradation has led to the collapse of shrimp farming, while the culture of milkfish was erratic and unpredictable. Any income from harvests often went towards paying back loans and many would lose ownership of their ponds. Polyculture in the form of integrated seaweed and milkfish or shrimp culture has recently been introduced. Through improved organization and planning within the village, producers began to receive a regular income (every two months) from the production of dried seaweed. Seaweed production has also improved the quality of the water and once again shrimp is being produced. In 2004 a group from the village known as KBTT won first prize in the seaweed category of a national aquaculture competition held by the Marine and Fisheries Department.

(Source: Mauksit, Maala and Suspita, 2005)

In the Philippines, where seaweed contributes the majority of the total mariculture production (Gonzales, 2006; Rosario, 2006), it is viewed by the government as one of the main species, along with milkfish and tilapia, that has the potential to generate both food and income for poorer groups (Box 6) (Gonzales, 2006).

The traditional or extensive culture of shrimp is also considered to hold potential in countries such as Myanmar (Maung Soe, 2006). However, these so-called "low-input extensive" and "extensive plus" systems rely on the stocking of shrimp from natural sources, with associated sustainability issues (Maung Soe, 2006). In India shrimp are often cultured on a rotational basis in rice fields known as *khazans* in Karnataka and *bheri* in West Bengal (Mohan, Sathiadhas and Gopakumar, 2006; Mukherjee, 2006) and result in production volumes of up to 0.5 tonnes per ha. Upon the establishment of these farms, employment is reported to have increased by between 2 and 15 percent, with the average income rising by between 6 and 22 percent and were reported as particularly important employment opportunities for women (Mohan, Sathiadhas and Gopakumar, 2006).

BOX 6

Seaweed (*Eucheuma*) culture in Guimaras Island, Western Visayas, Philippines

In 2001, the local government unit of San Lorenzo requested the Bureau of Fisheries and Aquatic Resources (BFAR) Region VI to introduce seaweed farming in Nadulao Island as a potential alternative to blast fishing. A fishers' organization with 17 members was formed to be responsible for four seaweed farms. Under the GMA, or *Ginintuang Masaganang Ani*, programme, the Seaweed Culture Project was created in collaboration with the Office of the Provincial Agriculturist and the Office of the Municipal Agriculturist. The site was expanded to include three other villages in San Lorenzo and 19 additional villages in the municipalities of Buena Vista, Nueva Valencia and Sibunag.

In April 2004, a Provincial Seaweed Development Council (PSDC) Technical Working Group (TWG) was formed, composed of representatives from government and commercial institutions. The PSDC-TWG then created the Seaweed Growers and Traders Association (SGTA), which now sells their products directly to Cebu exporters. There are now 16.65 ha under cultivation and benefiting 162 farmers. In 2005 the beneficiaries sold over 6 tonnes of fresh seaweed and 22 tonnes of dry seaweed valued at US$14 977. Farmers who were interviewed reported that the supplementary income from seaweed culture kept them away from illegal fishing activities and enabled them to send their children to school.

(Source: Gonzales, 2006)

However, extensive systems are subject to particular constraints, in particular the access to and availability of sites. Due to their extensive nature, such practices require access to relatively large areas of near-shore and coastal land and therefore exclude landless individuals and can also lead to resource use conflicts.

Mariculture market chains and coastal communities

Mariculture is constrained as a livelihood option for resource-poor people by their lack of access to capital, capacity-building and other resources; high capital investment costs; limited access to sites, markets and processing infrastructure; and the potential for resource use conflicts. However, the increasing international trade and exports from LIFDCs offer other opportunities. The market chains for the supply, production and export of aquatic products such as live reef fish, ornamental reef fish, shrimp and seaweed are typically defined by their complexity, which facilitates the inclusion of a wide range of stakeholders involved in the supply of inputs, production, harvesting, product marketing and consumption. Many of these stakeholders are classified as income-poor, and many are women who are heavily involved in the processing of aquatic products throughout Asia (for example in Viet Nam where women account for 90 percent of the labour force) (Macfadyen *et al.*, 2003; Nguyen, 2006). Appendices II and III demonstrate this complexity and describe a typical market chain for shrimp production in Viet Nam and, although not strictly a mariculture activity, a market chain for the collection and export of ornamental fish from Mindanao, Philippines to the United Kingdom.

Risks to mariculture development

Pollution and environmental degradation have the potential to impact heavily on mariculture and poorer stakeholders who are often less well equipped to deal with risk and livelihood shocks. Other risks, such as mariculture's reliance on wild seed collection and the use of fish in feed sources, demand solutions, some of which may provide opportunities for the inclusion of poorer groups.

Ecosystem degradation

One of the main risks to mariculture development is the degradation of the ecosystems that provide key environmental goods and services. Prime among these are the services that coral reefs and mangroves provide (UNEP-WCMC, 2006). These are a valuable resource for coastal communities and often act as a nursery for many fish species (Haylor *et al.*, 2003; FAO/NACA, 2003; UNEP-WCMC, 2006), including mariculture species such as grouper. In purely monetary terms, recent estimates have placed the value of coral reefs at between US$ 100 000 to 600 000 per hectare per year and the value of mangroves at between US$200 000 to 900 000 per hectare per year (UNEP-WCMC, 2006). Increasingly these systems are under the threat of degradation from a range of anthropogenic factors (Burke, Selig and Spalding, 2002; Chou, 2000; FAO, 2003a; Haylor *et al.*, 2003; NACA and FAO, 2003; Silvestre *et al.*, 2003; UNEP-MCMC, 2006). This is particularly severe in Southeast Asia, which accounts for 27 percent and around 43 percent of the world's reefs and mangroves, respectively (Burke, Selig and Spalding, 2002; UNEP-WCMC, 2006). Ecosystems that can no longer provide their full ecological services have an economic and social cost that often can be felt both locally and many miles away (UNEP-WCMC, 2006). The degradation of corals and mangroves may cause:

- reduced fish catches and tourism revenues in coastal communities and potentially a loss of food security;
- loss of export earnings; and
- increased coastal erosion and destruction.

Coral reefs

The main threats to coral reefs are coral bleaching and death due to climate change and increased El Niño events, over-fishing, and unsustainable and destructive fisheries practices such as dynamite and cyanide fishing. Other factors include habitat destruction and sedimentation through coastal development (Table 8).

TABLE 8

Anthropogenic threats to coral reef biodiversity in selected Southeast Asian countries (Source: Chou, 2000)

Country	Over-exploitation	Destructive fishing	Sedimentation	Pollution
Cambodia	X	X		
Indonesia	X	X	X	
Malaysia	X	X	X	X
Philippines	X	X	X	X
Thailand	X		X	X
Singapore	X		X	
Viet Nam	X	X	X	X

There is regional diversity in the state of reef decline but the situation in Southeast Asia is described as serious and probably under the greatest threat from human activities (Burke, Selig and Spalding, 2002). Some 88 percent of Southeast Asia's reefs are severely threatened. The situation is especially severe in Cambodia, Singapore and Taiwan Province of China where 100 percent of reefs are at a medium or higher level of threat[2], followed by the Philippines (98 percent), Viet Nam (96 percent), China (92 percent), Indonesia (88 percent) and Malaysia (88 percent).

Mangroves

Global trends in mangrove systems indicate a similar pattern of decline (Silvestre *et al.*, 2003; UNEP-WCMC, 2006), and the total area covered by mangroves worldwide has now fallen from 19.8 million ha in 1980 to below 15 million ha (FAO, 2003b), or 25 percent of the extent found in 1980. Mangrove deforestation continues, although at a lesser rate than in the 1980s (1.1 percent per year compared to 1.9 percent per year) (FAO, 2003b). Many fish species use mangroves as nurseries or make use of these systems in some part of their life cycle; mangroves also provide sources of feed and act as a buffer to the impacts of severe weather events (FAO/NACA, 2003; UNEP-WCMC, 2006). The disturbance and alteration of mangrove habitats therefore lead to a departure of fish populations and other nekton that will not easily return to the impacted zone (FAO, 2003b; FAO/NACA, 2003) and ultimately to impoverished livelihoods for those who depend upon the fishery sector.

The main threats to mangroves include clearance for industrial and coastal development, salt production and shrimp pond construction. However, due to an increased awareness of the important roles mangroves play in the marine food web and in providing wood and non-wood forest products and coastal protection, most countries in the region have long since restricted or banned the conversion of inter-tidal mangrove into shrimp pond culture. Where the demand for land for agriculture or aquaculture (e.g. to increase production of rice and fish for local consumption) or for infrastructure development necessitates the conversion of mangrove areas, the decision should be based on the results of a thorough Environmental Impact Assessment (EIA), including a valuation of all the direct and indirect benefits mangroves provide to livelihoods and the environment. Therefore, the use of these systems must seriously consider the value of the services they already provide to ensure the regional sustainability of fisheries production and the ecosystem services on which they rely. At the minimum, decisions on the use of reefs and mangroves must be based on ecological and livelihoods-based research to ensure that returns from an activity introduced into mangroves (such as aquaculture) are far greater than the opportunity costs of the services that the targeted mangroves provide (FAO/NACA, 2003).

Wild seed collection vs small-scale hatcheries

The reliance on wild-caught seed for mariculture purposes is another potential constraint, since not only do such activities have the potential to cause over-fishing and ecosystem degradation, but discarded by-catch from seed collectors also impacts upon future fisheries and fishers' livelihoods (Suspita, 2006). The development of small-scale or backyard hatcheries, however, can help alleviate this risk and still involve poor stakeholders in mariculture activities (Gonzales, 2006; Sim *et al.*, 2005a; Suspita, 2006). Small-scale hatcheries are those where the capital costs are relatively

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[2] Based on the Reefs at Risk in Southeast Asia (RRSEA) model and the Reefs at Risk Threat Index. The index is designed to highlight areas where, in the absence of good management, coral reef degradation might be occurring or where it is likely to happen in the near future, given ongoing levels of human activity. The threat indicators therefore gauge current and potential risks associated with human activities, not actual reef condition (Burke, Selig and Spalding, 2002).

low, technologies are accessible, and that focus on the larval rearing and nursery aspects of fingerling production. They do not hold broodstock; instead they purchase fertilized eggs from larger hatcheries. They offer the advantages of low capital costs, simple construction, ease of operation and management, flexibility and use for a range of marine fish species, as well as the potential for quick economic returns (Sim *et al.*, 2005a).

Fish feed

Mariculture, particularly the production of marine finfish and lobster, still relies heavily on the supply of "trash fish," which can be considered inappropriately named, as this protein source would never be wasted but used for other purposes (Sim *et al.*, 2005b). The increased use of this resource in mariculture therefore has the potential to lead to resource use conflicts and impact on people's food security and livelihoods (Suspita, 2006). An increased demand for trash fish could also encourage over-fishing, destructive fishing practices and environmental degradation. Other problems with its suitability for mariculture use include a short storage life, seasonal variation in supply, wastage due to disintegration and the pollution from these causes. It has the potential to act as a disease or parasite vector (Sim *et al.*, 2005b). Significant progress has been made in the development of partial or full feed alternatives (Sim *et al.*, 2005b; Suspita, 2006) and like small-scale hatchery production, small-scale feed production provides an opportunity for poorer stakeholders to become involved in mariculture activities (Sim *et al.*, 2005b; Suspita, 2006).

Intensification and consolidation

New technologies are likely to accelerate the intensification of inland and coastal aquaculture that has already occurred. Environmental legislation is likely to contribute significantly towards this, as controlling pollution requires capital investment. In addition, if developing countries adopt aquaculture subsidies similar to those already present in China and industrialized countries (e.g. cheaper land, lower taxes and tariffs), then the large-scale, capital-intensive model of aquaculture is likely to emerge at the expense of small-scale systems (Delgado *et al.*, 2003). Weak legislative frameworks for the promotion or protection of access rights for rural and coastal communities and people will also aggravate this issue. In addition, growing international markets and the increasing power of export markets will likely cause market chain consolidation, which could force out smaller operators (Macfadyen, Phillips and Haylor, 2005).

Trade barriers

The risks inherent with international trade are often passed on to the poorest stakeholders (Macfadyen, Phillips and Haylor, 2005), and aquaculture processing countries in Asia have to address a wide array of trade issues (Bueno, 2004), including tariff and non-tariff trade barriers.

The aquaculture industries of the Asia-Pacific region are susceptible to the imposition of tariffs by importing countries, and over the last few years the United States of America has successfully placed import tariffs on Vietnamese catfish (*tra* and *basa*) and on shrimp from a range of Latin American and Asian countries (Bulcock and Savage, 2003, 2004, 2005). Such measures can have a dramatic effect on national aquaculture industries and can often lead to poorer stakeholders becoming marginalized (Box 7).

BOX 7
The impact of shrimp trade tariffs in Viet Nam

In 2004 under the direct impact from an anti-dumping case, Vietnamese shrimp export and processing activities declined, with some fish export-processing companies ceasing operations. The case has seriously affected the export turnover and trading activities of shrimp companies, especially those with established market ties to the United States of America. Prices of shrimp dropped quickly (by at least VND 10 000/kg (US$0.67/kg) for every size of shrimp. Collectors of shrimp were most affected, as processing companies not only reduced the quantity they required but also stopped informing collectors of the purchase price. In addition, when prices fall, shrimp farmers' incomes are also reduced and as a consequence, farmers find it difficult to prepare their finances for the next culture cycle. The fall in prices also has also had knock-on effects for others involved in the market chain, such as those working in shrimp hatcheries, as the demand for seed is lower.

(Source: Macfadyen, Phillips and Haylor, 2005; Nguyen, 2006)

It is also becoming increasingly important for producers to assume responsibility for the quality of the product and the actions taken in producing it (Bueno, 2004). In a recent poll in the European Union (EU) by the Seafood Choices Alliance on consumer attitudes towards seafood and the state of the world's ocean, 79 percent said that the environmental impact of seafood is an important factor in their purchasing decisions (Bulcock and Savage, 2005). Environmental and social responsibility issues are therefore joining food safety and quality as requirements to market access and can sometimes be used as so-called non-tariff trade barriers by importers. As most farms in Asia are small and producers are sometimes not well organized, it is difficult for farmers to comply with international standards (Bueno 2004). There have been several recent and high-profile trade conflicts, including a zero tolerance policy by the EU, over the use of prohibited antibiotics (Bueno, 2004; Bulcock and Savage, 2003, 2004). However, this growing awareness and demand for environmentally sensitive aquaculture also presents opportunities (Bueno, 2004; Macfadyen, Phillips and Haylor, 2005). In the same Seafood Choices Alliance poll, 86 percent of consumers would prefer to buy seafood that is labelled as "environmentally responsible". Consumers added that reassurances that the product was environmentally sound were more important than price. In fact, 40 percent were willing to pay 5–10 percent extra for seafood identified as eco-friendly (Bulcock and Savage, 2005). Environmentally sensitive aquaculture makes good business sense and has helped push efforts to promote the adoption of environmentally and socially responsible farming practices through appropriate standards or codes of conduct and the discussion of suitable certification programmes (Bueno, 2004).

THE WAY FORWARD

Actions needed

Livelihood diversification

The diversification of economic activities is seen as an important part of the development of economies. With respect to poverty reduction, diversification is considered as:

- a coping strategy of poor people to deal with increasing competition, and therefore a familiar strategy within coastal communities; and

- a development strategy enabling poorer members of society to graduate out of poverty (IMM, CFDO and CBNRM LI, 2005).

Therefore, it is not surprising that the rural development strategies of governments sometimes focus on the role of livelihood diversification as a way of reducing poverty (IMM, CFDO and CBNRM LI, 2005). In addition, governmental agencies and nongovernmental organizations (NGOs) that are concerned with the sustainable use of natural resources are promoting livelihood diversification as a way to encourage people to move away from exploitative and destructive use of those resources (IMM, CFDO and CBNRM LI, 2005). Mariculture presents an opportunity to diversify coastal livelihoods and provide an alternative income-generating activity for coastal communities and those involved in destructive fishing practices (Haylor *et al.*, 2003). It also has the benefit of being an alternative source of fish protein. However, before promoting pro-poor mariculture activities, there are many specific issues that must be addressed. These vary according to the type of activity, and must be considered in a context-specific manner, but typically they include:

- the relatively high capital costs and skills required for mariculture;
- the right focus of mariculture activities with respect to gender and age and its ability to integrate with existing aspects of coastal management, livelihoods and resource uses;
- the willingness and ability of people to adopt alternative livelihoods (or to diversify their livelihoods);
- the ability of farmed products to replace wild-caught products in markets;
- the environmental footprint of the activities;
- seed, broodstock and feed supply; and
- unproven economic, technical and environmentally sustainability factors (Briggs 2003).

In some countries, there are also questions regarding access to technology, extension support, capital and security (FAO/NACA, 2003). Therefore, key factors to the development of pro-poor mariculture in the region include the introduction and extension of appropriate mariculture technologies and activities, the provision of support services, and the development and implementation of sustainable mariculture practices based on an analysis of the goods and services provided by ecosystems and their carrying capacity.

Pro-poor international trade

The opportunities presented by domestic and international trade and their market chains should also be recognized, and effective and equitable ways of linking coastal communities into regional, national and global markets found to achieve long-term livelihood improvements (Macfadyen, Phillips and Haylor, 2005). In some cases, the building of the capacity of fisheries administrations to deal with international trade issues is required. There is also the need to focus on issues regarding the reliability and quality of the product. However, once again there is limited access to credit, and therefore pro-poor trade initiatives could include support for micro-finance programmes (Macfadyen, Phillips and Haylor, 2005).

Strategies for development

Pro-poor mariculture policies

The opportunities that the growth in aquaculture and mariculture production and the international trade in their products present for livelihoods diversification, and the actions needed to achieve this, have been recognized by regional governments, and this recognition is now being voiced through government policies and statements.

For instance, in Viet Nam in January 2006, Decision 10/2006/QD-TTg was issued by the Prime Minister, approving a Master Plan for the fisheries sector development until 2010 with perspectives for 2020 (Bulcock and Savage, 2005; Nguyen, 2006). In this legal document, the need to develop fisheries into a major commodity was detailed, along with a call for increased productivity, production and competitiveness, characterized by product diversity, to meet the increased demand from domestic consumption and foreign trade. The decision also outlined the importance of ensuring the sustainable development of the aquaculture and fisheries sector (Nguyen, 2006). In the Philippines in response to the president's recent "10–Point Agenda", which focuses on job generation, the Bureau of Fisheries and Aquatic Resources (BFAR) has begun to identify areas in which mariculture could contribute towards providing small-scale fishers and coastal communities with alternate types of employment (Gonzales, 2006). The Government of Pakistan is currently emphasizing the importance of the fisheries sector in creating food security and income-generating opportunities, and national fisheries policy is currently being formulated (Wattoo, 2006).

Adopting a livelihoods-based approach

Livelihoods in coastal areas and the factors that affect them are complex (IMM, CFDO and CBNRM LI, 2005). Therefore, interventions that intend to help reduce poverty in these areas need to understand this complexity and how it evolved (IMM, CFDO and CBNRM LI, 2005). However, the majority of efforts to support livelihoods diversification have tended to be supply-driven and focused on single-issue solutions. Services such as mariculture have been offered to communities to address perceived needs without any real understanding of the underlying causes of the lack of livelihood diversification (IMM, CFDO and CBNRM LI, 2005). As a result, rural development efforts tend to be well supplied with development initiatives but lack the corresponding level of livelihood improvement (IMM, CFDO and CBNRM LI, 2005).

Therefore, to implement effective pro-poor mariculture strategies, an acknowledgement and understanding of the complex nature of livelihoods in poor coastal communities is essential. The use of mariculture as a potential livelihood option for poor rural and coastal communities must be based on a careful and realistic assessment of communities' needs, priorities, access to resources and the vulnerabilities people and communities face (Gonzales, 2006; Suspita, 2006; NACA/FAO, 2000). Due to the complex and shifting nature of coastal communities and livelihoods, it is possible that mariculture may actually adversely affect the livelihoods of rural and coastal communities by diverting food resources, degrading the environment, disrupting access to common resources and therefore disrupting already vulnerable livelihood strategies. Therefore, for research and development in mariculture to support poor people's livelihoods, people and communities must be placed at the centre of development planning, where an understanding of their livelihoods will require a comprehensive and broad-based approach that goes beyond a focus on assessments of locally available resources and technologies.

The adoption of livelihoods-based approaches is one such method. These involve learning about the resources that people and communities command, the choices they make and the circumstances of their livelihoods. They are therefore better able to identify poor people and understand the contexts of poor rural and coastal communities' lives. Such approaches are increasingly becoming endorsed by international organizations (such as the Food and Agriculture Organization of the United Nations, FAO), development organizations, donors (including the United Kingdom's Department for International Development, DFID) and governments, notably in Asia-Pacific. The Network of Aquaculture Centres in Asia-Pacific (NACA) and its Governing Council of 17 Asia-Pacific governments recently endorsed a regional consensus on the value of livelihoods approaches,[3] calling for:

- investment in livelihoods approaches that go beyond a focus on resources and technology alone;
- the participation and shared understandings of all stakeholder groups to build community capacity, trust and ownership; and
- livelihoods approaches and analysis to be a bridge between communities and policy-makers in the assessment of the impact of decision-making processes and policies on people.

Identifying appropriate entry points

Through a consideration of people's needs and priorities, livelihoods-based approaches can therefore help better identify:

- whether mariculture interventions are appropriate; and
- if so, whether they can help to identify appropriate low-risk entry-points where coastal communities (including women) can become involved in mariculture activities and where they can receive maximum benefits (Gonzales, 2006; Maung Soe, 2006; Mukherjee, 2006; Nguyen, 2006; Suspita, 2006).

They can also help identify the most suitable livelihoods along the mariculture market chain and can often recognize potential income-generating opportunities such as backyard hatcheries and feed production.

Integrated coastal management approaches

The increase in mariculture production and trade of marine products also presents a challenge to ensure sustainable development and that a balance between valuable ecosystems and reducing poverty is preserved (Macfadyen *et al.,* 2003). The Indian Ocean tsunami has brought issues such as coastal planning, resource use and potential resource use conflicts into the spotlight, and there is continued interest in the issues concerned with coastal management. As a result, it is widely accepted that the introduction of mariculture practices should be part of a coherent wider programme of intervention in coastal resources management, and that these programmes should involve the participation of resource users in the design of interventions along with partnerships with relevant institutions (Haylor *et al.*, 2003). Effective management is the key, although sometimes inadequate across the region. Improved community-based coastal resources co-management is encouraged in collaboration with government and private sector and aimed at addressing the lack of integration of mariculture in development plans. Such approaches can be consolidated under well-managed Marine Protected Areas (MPAs) (Box 8). MPAs are internationally recognized and in operation throughout the Asia-Pacific (Briggs, 2003; IUCN Pakistan, 2003; Gonzales, 2006; Santos, Pador and De La Torre, 2003; Suspita, 2006; Nguyen, 2006).

Pro-poor trade approaches

International trade in seafood products and the associated seafood market chains within each country offer many opportunities for the inclusion of poor people and the improvement of their livelihoods. However, there is a low level of awareness regarding this key finding. The importance of the seafood trade needs to be much more widely appreciated along with a greater awareness of the role it can play in poverty reduction (Macfadyen, Phillips and Haylor, 2005). Trade issues and market chain analyses need to be incorporated into poverty reduction strategies, including those focused on mariculture development. The capacity of development of country governments and fisheries administrations also needs to be supported for them to be more proactive in engaging with international trade issues to ensure that trade is beneficial to small-scale and poor producers,

[3] The FAO-NACA Regional Workshop on Aquatic Resources and Livelihoods: Connecting Policy and People, 17–19 March 2005 in Los Baños, Philippines.

rather than being reactive to problems once they have occurred. Such capacity-building could involve improvement in trade negotiation skills, product quality issues, developing and following through marketing strategies and promotional tools, analysis and understanding of people's livelihoods and how best to support them and improve policies, how to adapt to health and safety measures in export markets, and monitor and respond to on-going developments in trade, methods of dissemination of trade-related information and support to all links in the market chain. Other key recommendations for improved pro-poor trade in Asia-Pacific are given below (Box 9).

BOX 8

Mariculture parks

Promotion of mariculture parks is one strategy through which BFAR intends to create livelihood opportunities for coastal communities and increase fish production. A mariculture park is described as "an industrial estate put in the sea for the fishing industry" where infrastructure (a pre-developed area complete with a road network, power, water and communication lines) and utilities (mooring system) are provided by the government and mooring space is leased to investors. The first mariculture park was formally opened in August 2001 in Samal Island in Davao Region.

(Source: Gonzales, 2006)

BOX 9

Key policy recommendations for improved pro-poor trade in Asia-Pacific

- The importance of trade in aquatic products needs to be more widely appreciated.
- The capacity of fisheries departments should be developed on issues such as trade negotiations, promotion and extension.
- Capacity in local-level organizations should be developed.
- Traceability of products must be encouraged.
- Development of fishery policy and trade policy must be participatory and include poor stakeholders and their representatives.
- Support improved communications regarding international trade, including raising awareness on the impacts of trade barriers.
- Pro-poor trade policy implementation must be backed up by wider local management of resources and good governance initiatives.
- Greater support for pro-poor trade research.
- Establish preferential tariffs for socially certified products.
- Focus on quality and reliability of supply.
- Support detailed studies on the impacts of certification schemes; and the potential of poor stakeholders to be marginalized by these needs to be recognized.
- Governments and donors should work through NGOs and their associated networks to reach poor stakeholders.
- Governments in Asia should examine whether parts of the international market chain can be encouraged to relocate to Asia.
- Support the increased availability of micro-finance.
- Complementary activities of those engaged in trade who remain poor should be investigated.
- Occupational health and safety issues should be incorporated in any eventual certification schemes.

(Source: Macfadyen, Phillips and Haylor, 2005)

CONCLUSIONS

Small-scale fishers and poor coastal communities in Asia-Pacific that had traditionally relied on coastal capture fisheries as a cheap source of animal protein are faced with an increasingly competitive and declining capture fisheries sector associated with increased food insecurity and unsustainable fishing practices. Therefore there is a need to support diversified coastal livelihoods and promote alternative and sustainable income-generating activities and sources of affordable fisheries products. Mariculture and the international trade in fishery products hold a great deal of potential towards achieving this. There is a wide range of small-scale mariculture-based technologies and practices available and in operation throughout the region. However, the livelihoods of poor coastal communities and people are complex and subject to particular vulnerabilities and risks that often lead to an increased level of marginalization as well as the failure of mariculture activities. For mariculture and the international trade in aquatic products to be truly pro-poor, a broad-based, people-centered approach is needed to understand coastal livelihoods more completely an identify context-specific and appropriate mariculture entry points that could be adopted as alternative income-generating activities. These livelihoods-based approaches could be incorporated into recognized and established integrated coastal management plans and policies such as MPAs to reduce resource use conflicts and encourage sustainability.

Finally, although the international seafood trade has been recognized as an important source of employment and income for poor coastal communities and in particular women, there needs to be more awareness of its pro-poor potential and more focus in this area in development strategies, government policy and institutions. This could include building the capacity of government and local-level institutions in understanding and dealing with issues specific to the trade in aquatic resources.

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APPENDIX I
Target communities and stakeholders identified by the country reviews

Country/Commodity	Target communities	
India[1]		
Shrimp culture	Farmers and workers, feed and seed suppliers	West Bengal, Kerala, Andhra Pradesh, Tamil Nadu and Karnataka states
Traditional rice-shrimp culture	Small-scale farmers and fishers and women	Coastal lowlands (Pokkali fields in Kerala, Khar lands in Goa, Khazans in Karnataka State and Bheri in West Bengal)
Green mussel farming	Small-scale farmers and fishers and women	
Lobster fattening	Small-scale farmers and fishers and women, seed and feed suppliers	
Crab farming	Small-scale farmers and fishers and women	
Edible oyster culture	Small-scale farmers and fishers and women	
Seaweed culture	Small-scale farmers and fishers and women	
Indonesia[2]		
Tambak mariculture	Ethnic groups	
Intensive mariculture	Migrant workers	
Seed collectors		
Seaweed culture	Farmers, women	Beksi District, Bali (US$0.30–0.60 month per household), Palu Bay, Central Sulawesi
Pearl culture	Low-paid cleaners	
	Crafters of discarded shells	
Mud crab culture	Farmers	
Mussel culture (*Perna* spp.)	Farmers	
Fisheries extension	Women in extension, research and education	

[1] Coastal communities of Tamil Nadu, Chennai, Pondicherry, Andhra Pradesh, Orissa and West Bengal and scheduled castes and tribes.

[2] Many people not listed as fishers are at least part-time harvesters of marine organisms

APPENDIX I
Continued

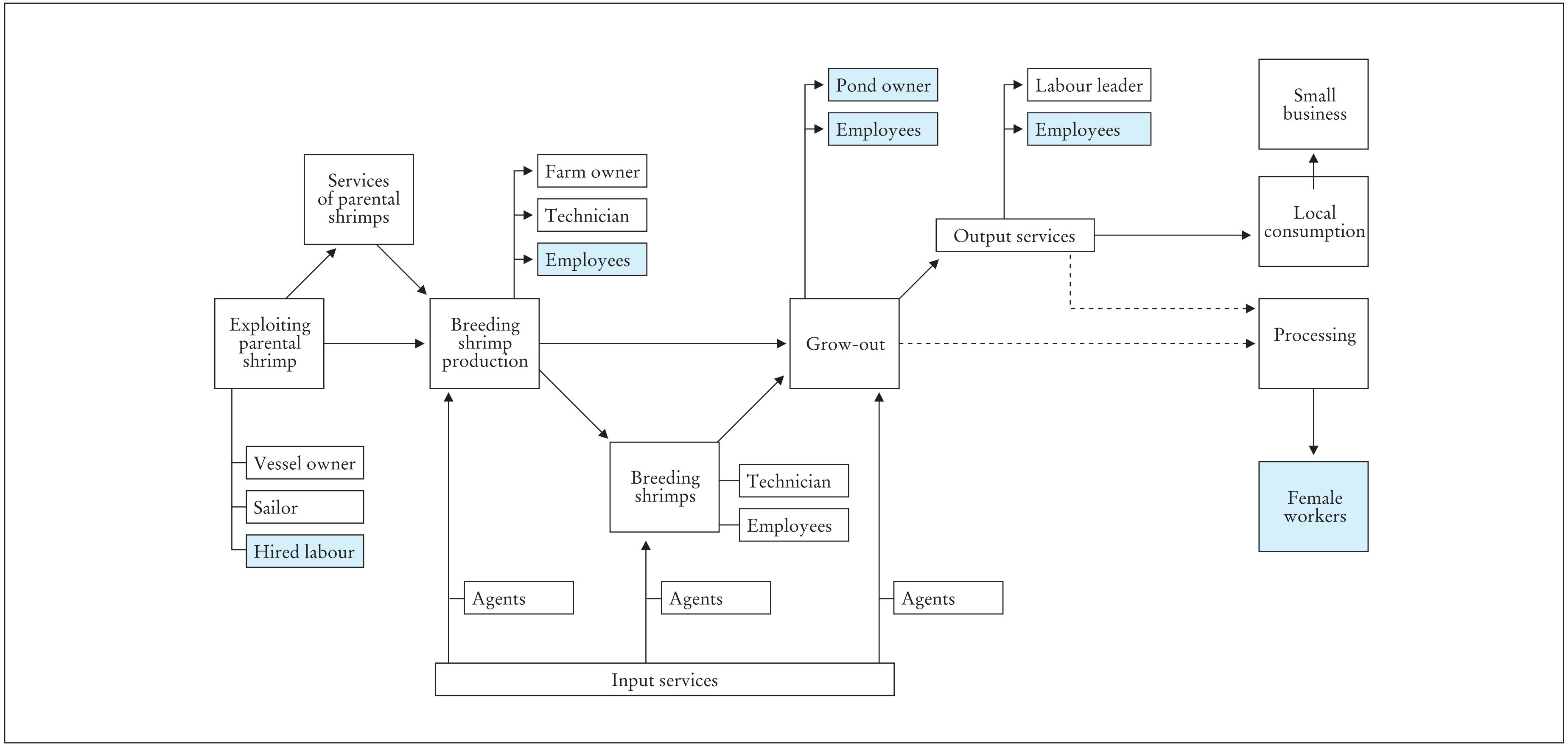
Country/Commodity	Target communities	
Myanmar		
Shrimp fry collection	Fry collectors, women and children	Rakhine State
Mud crab and grouper cage farming	Cage farmers	Rakhine State
Shrimp culture (extensive, extensive plus and semi-intensive)	Small-scale operators, caretakers, pond preparation labourers, harvest and post-harvest labourers, sorters, buyers, traders and exporters	Rakhine State, Yangon, Tanintharyi Division
Shrimp hatcheries	Operators, caretakers, tank cleaners	27 shrimp hatcheries, 12 run by DoF and 15 private
Grouper cage culture	Small-scale operators/farmers and grouper fry collectors (700 to 800 fishers)	Southern, western parts of Myanmar: Myeik Archipelago and Gwa Township
		Ayeyarwady and Tanintharyi divsions
Sea bass (*Lates calcarifer*) pond culture		Ayeyarwady and Rakhine states
Mud crab fattening in ponds and cages and feed preparation	Farmers and women	Myeik
Collection of live lobsters (*Panulirus*) and *Squilla* or mantis shrimp	Collectors and buyers	
Mother of pearl culture	Hired labourers, divers and cleaners	Myeik and Tanintharyi divisions
Post-harvest activities	Women	

APPENDIX I
Continued

Country/Commodity	Target communities	
Philippines		
Milkfish cage operation	Small-scale cage operators, caretakers, extra feeders, pre-operation workers/labourers, small-boat operators delivering farm inputs, fish vendors and viajeros	Bolinao, Anda na Sual in Western Pangasinan, Central Pangasinan, Masinloc-Palauig areas in Zambales; Santo Tomas in la Union, Quezon, Cavite, Negros Occidental, Samal Island in Davao
Seaweed farming in coastal waters	Small-scale farmers, women, farmers associations, producers and traders association, seed suppliers, buyers, processors and exporters	Tawi-tawi in Autonomous Region in Muslim Mindanao (ARMM), Mimaropa Region, Zamboanga, Guimaras Island, Panagatan and Caluya in Antique in Western Visayas
Oyster and mussel farming	Farmers and women	
Fish and seafood trading	Fish vendors, peddlers and women peddlers	
Grouper cage culture	Small-scale operators, small buyers and seed suppliers	Day-asan, Surigao, Caraga Region in northeastern Mindanao, Eastern, Western and Central Visayas, Pangasinan, Cavite, Mindoro, Quezon, Masbare, Bulacan, Cagayan, General Santos, Zamboanga del Sur and Bais City in Negros Oriental
Wild fry collection	Fry collectors, concessionaires and other middlemen	Cabangan, Botolan in Pangasinan, Cavite, Mindoro, Quezon, Masbate, Bulacan, Cagaya, General Santos, Zamboanga del Sur and Negros Oriental
Shellfish gleaners and seafood vending	Women and children	
Live fish, ornamental fish collection	Grouper collectors, ornamental fish collectors, abalone, sea horse, sea cucumber collectors (seasonal), seasonal octopus fishers, packers, women packers and children running errands in "financiers" facilities	
Commercial fishing	Captain and crew	
Viet Nam		
Agriculture and animal husbandry	Crop farmers, migrant workers, hired labourers, livestock and poultry raisers	
Aquaculture products processing	Women	
Commercial fishing	Hired workers	Receiving US$13.33 per trip
Hatcheries	Hired workers	Income = US$33.33–40.00
Shrimp farming (*Penaeus monodon and Litopenaeus vannamei*)	Small-scale operators, shrimp farm employees, feed suppliers, fry suppliers	
		Income = US$33.33–40.00
Shrimp processing factory (seasonal; working 12–15 hours per day during peak season)	Hired factory workers and women workers	Income = US$1.67 per day State-owned = US$23.33–80.00
Fish and lobster sea-cage farming	Small-scale farmers, landless people	Khanh Hoa benefited
Shrimp-mangrove farms	Farmers	Mekong Delta
Cage culture		Bai Tu Long and Ha Long bays
Mollusc, crab, seaweed farming		Long An to Ca Mau

APPENDIX II

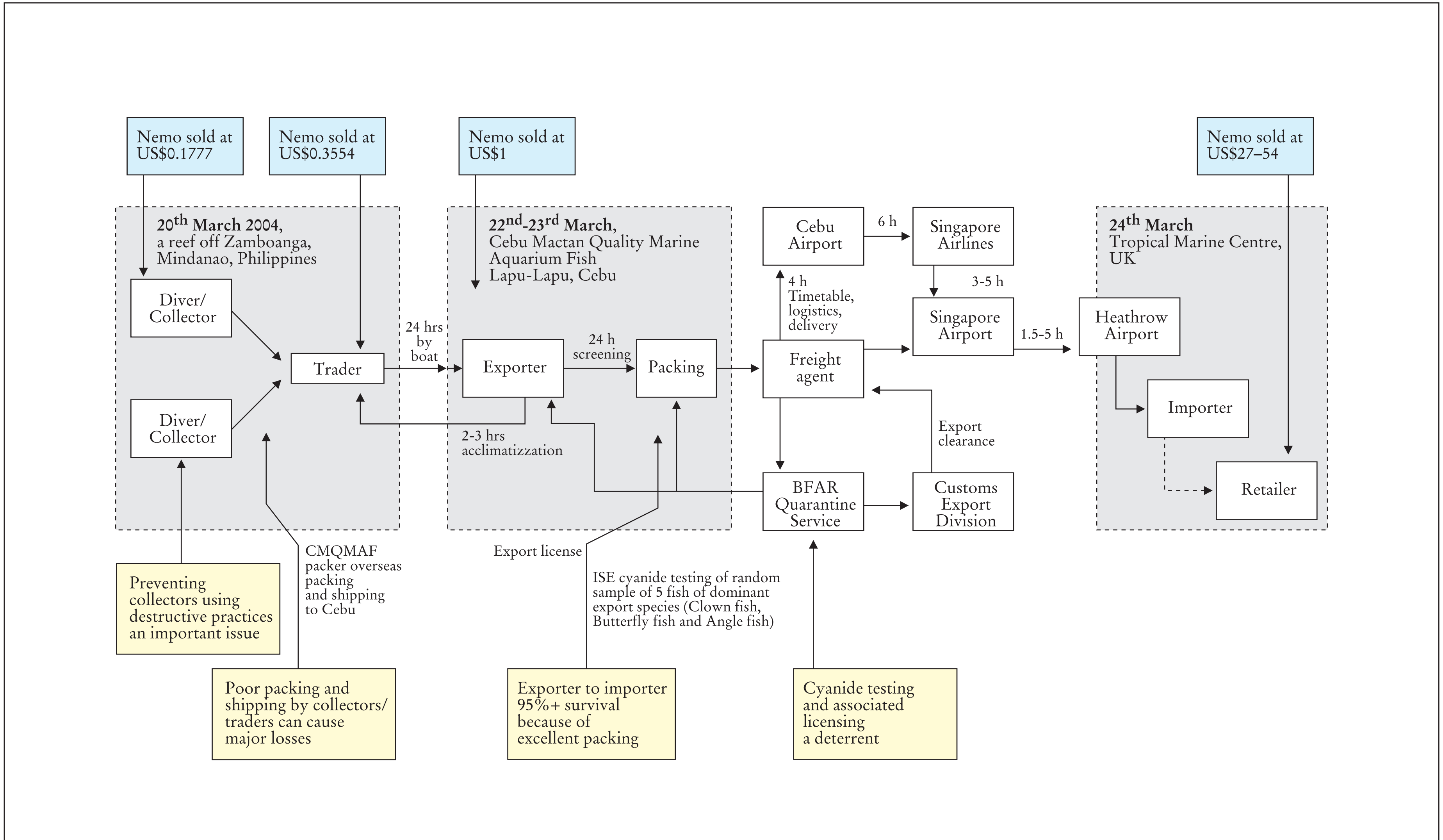
The market chain for shrimp in Thua Thien Hue, Viet Nam (From Macfadyen, Phillips and Haylor, 2005)[1]



[1] The blue-shaded areas indicate potential roles for income-poor stakeholders.

APPENDIX III

Trading Nemo – The market chain of marine ornamentals from Mindanao to Manchester (From Macfadyen, Phillips and Haylor, 2005)



Mechanisms for technology transfer

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INTRODUCTION

Applied research activities on existing and potential mariculture species are being carried out throughout the region by specialized national research facilities. Many of the commercial marine species are farmed regionally and rarely confined to the industry of any given country. The transfer of farming technologies and better practices in the region through a strengthened collaborative mechanism could further support the development of the sector and ensure that lessons learnt are widely shared. The objectives of this review are to:

- review existing mechanisms for technology transfer and propose alternatives for effective dissemination of research and development (R&D) to farmers and other stakeholders;
- identify present training activities and future training requirements for the sustainable development of mariculture; and
- identify centers of excellence in various forms of mariculture.

The information summarized below on regional mariculture research, training activities and future needs has been compiled from a variety of sources including:

- country review papers for this workshop;
- the Report of the Expert Workshop and Regional Aquaculture Review for Asia (November 2005);
- the Report of the 8th Network of Aquaculture Centres in Asia-Pacific (NACA) Technical Advisory Committee (October 2005);
- the Report of the 17th NACA Governing Council, (23–28 February 2006);
- NACA publications (reviewed content from 2001–2006);
- Asia-Pacific Marine Finfish eNewsletter (reviewed content from 2001–2006)
- institutional websites (content reviewed as of February 2006); and
- profile of NACA Centres (December 2001).

EXISTING AND ALTERNATIVE MECHANISMS FOR TECHNOLOGY TRANSFER

Existing mechanisms

Most of the existing mechanisms used to transfer mariculture technology are largely standard practices in fisheries and aquaculture (or more broadly, in agriculture). They may be loosely categorized into the four following areas:

Hands-on training-short courses, study tours, training schools and on-the-job experience

Due to the highly technical nature of some aspects of mariculture, particularly hatchery technology, hands-on training is often the most practical mechanism for technology transfer. Short, intensive courses on specific aspects of mariculture (such as the Regional Grouper Hatchery Production Training Course offered annually by Indonesian research centers in collaboration with NACA) are among the most common technology transfer mechanisms cited by countries. Hands-on mariculture training opportunities are also provided through vocational training schools (as those in Australia and Malaysia) and on-the-job in some research centers where farmers may work for a period in a government station to gain experience in the practical and technical aspects (as in Indonesia). Demonstration farms and exchange visits to exceptionally good private farms are used in some countries to raise awareness and encourage the private sector to enter into new industries or to adopt new practices (as in India, Indonesia and Thailand).

While hands-on training can provide practical and effective learning opportunities for transferring technology between all kinds of stakeholder groups, there is a shortage of specialized facilities where such training can take place and the number of opportunities/placements is generally not sufficient to meet demand. Participants often have to travel great distances at considerable expense, so that such training is accessible only to people who are relatively wealthy or have a sponsor (government, research and industrial-scale farmers).

Extension services, seminars and discussion groups

The accessibility issues that small-scale producers and rural communities face in centralized training opportunities are widely recognized. Most governments therefore employ a range of "mobile" mechanisms to bridge the gap with rural communities and take training opportunities to the producer.

Extension officers are a traditional technology transfer mechanism providing technical support to producers through on-farm advice, local seminars, distribution of publications and other information, and even provision of mobile laboratory services on water quality or health (as in Thailand). Extension officers can also play an important role in the social cohesion of local producers. The scale on which extension officers are deployed varies widely between countries, with officers serving individual communities (People's Republic of China) to entire states (Australia). While the provision of a decentralized extension network can improve accessibility to information for rural communities, it is expensive. In most countries it is generally accepted that extension services are in decline and do not have sufficient staff or resources to meet demand. They may function most effectively where there are organized groups of producers with which they can interface. The role of nongovernmental organizations (NGOs) involved in rural development as an alternative avenue for the delivery of extension service is well recognized by some governments. Such NGOs may provide training or work in partnership with appropriate groups (as in India and Thailand).

A common issue with regard to mariculture is that existing extension staff may not have sufficient technical training to adequately support farmers (as in Cambodia, China, India and Thailand), particularly with regards to emerging technologies.

While most extension services are funded by the public sector, farmer groups may employ their own extension staff to provide specialist services (notably in aquatic animal health), although this is seldom seen outside of industrial-scale producer groups (as in Australia, but being considered by the Marine Products Exports Development Authority [MPEDA] in India).

Publications

Printed publications are a mainstay of technology transfer employed by virtually all governments as a (relatively) cheap mechanism for reaching large numbers of producers, although where cost-recovery policies are pursued, cost is still often a significant issue both for the publisher and for the end user. As stand-alone products, the usefulness of publications is constrained by many factors, including the literacy and technical ability of the target stakeholders, and so they need to be prepared with due consideration of the needs of the target group, for whom they often play a supporting role in training courses and other ways of learning. An issue that remains understated is that the accessibility of printed matter is often a significant issue for people in rural communities, just as distribution can be an issue for the publisher. Producing a publication is relatively simple, but ensuring that it is widely available, accessible and affordable to the people that actually need it is far more difficult. In many ways, the problems that rural communities face in accessing printed media are not dissimilar to those they face in accessing the web.

Mass media

Regular television and radio programmes are utilized by both governmental authorities and the private sector as a mechanism to keep farmers informed of developments, emerging issues and improved practices. These range from current affairs segments in broader agricultural programmes (as in Australia) to dedicated documentary segments (as in Thailand) and talk-back programmes where farmers may "call in" (as in Cambodia). Clearly such devices have enormous potential, although agricultural programmes tend to be broadcast outside of peak hours.

Alternative mechanisms

In a climate of increasing demand for knowledge and diminishing extension resources, the transfer of technology to a large decentralized stakeholder base will become increasingly difficult and require fresh approaches. Some promising alternative approaches to technology transfer are described below.

Information access surveys

An Information Access Survey (IAS) is not a mechanism for technology transfer in itself, but rather a tool that can help make sensible decisions about the best ways to communicate with different groups of stakeholders. The purpose of an IAS is to conduct an objective assessment to:

- identify key issues about people and what information needs they have;
- identify what media sources are available, what strategies people use to get their information and how cost-effective these are; and
- suggest the most appropriate methods of communication that are useful for different groups of people.

An IAS should:

- take into consideration the needs of the target group;
- involve as many people as possible;
- be socially and culturally acceptable;
- be flexible, so that it can be modified to suit different circumstances; and
- provide recommendations that are easy to put into practice.

For each stakeholder group, issues to consider/include in preparation of an IAS include:

- the geographical area of the survey;
- the existing communications networks available to target stakeholders;
- the needs of the stakeholders;
- the kinds of information that would be useful to them;
- how this information would help them;
- how people prefer to get this kind of information;

- mitigating social, political or cultural factors; and
- what techniques work well, and why.

An IAS provides an indication of how effective different media are in reaching target stakeholders and forms the basis for developing an integrated communication strategy. Some approaches are likely to be more useful than others or may only be useful to part of the target group. It is quite likely that an IAS will reveal that an integrated or mixed approach using multiple strategies may be most effective. IAS's have been conducted by the NACA STREAM Initiative for Cambodia, Viet Nam and the Philippines.[1]

Farmer associations (aquaclubs)

The formation of farmer associations is an approach that has demonstrated excellent potential as a mechanism to facilitate technology transfer, both between stakeholder groups and within farmer communities. In India, MPEDA in cooperation with NACA, the Indian Council of Agricultural Research (ICAR), the Australian Centre for International Agricultural Research (ACIAR) and the Food and Agriculture Organization of the United Nations (FAO) has provided support to bring clusters of shrimp farmers together into cooperative associations to implement Better Management Practices (BMPs) as part of projects on shrimp health and coastal zone management. The groups, locally known as "aquaclubs", were initially established to engage farmers in the development of locally appropriate BMPs and to demonstrate and promote the advantages of working as a group to plan their crops. The group collectively manages common resources such as the water supply, thus reducing inter-farm interference, reducing the impact of disease and substantially increasing survival, size, yield and price received for the crop. Similar approaches have been applied in Viet Nam with equal success.

The benefits of aquaclubs are that they:

- serve as focal points for extension services, leveraging the accessibility and impact of better farmers and available extension staff among small-scale producers, as well as providing good opportunities for farmer-to-farmer learning;
- provide a mechanism for rapid implementation of new technologies or BMPs across the group, such as food safety directives from export markets or traceability systems;
- provide economies of scale in purchasing technical services, such as the testing of seed for health problems, which in turn facilitates the access of small-scale farmers to these services;
- provide a mechanism for self-regulation, as there is considerable economic incentive and peer pressure for farmers to participate and comply with the groups' management principles;
- provide increased market power in negotiating prices for inputs and for the sale of the harvest;
- are self-sustaining – as they are economically viable they may also be independent of government support and maintained by the farmers themselves.

Farmer associations have good potential in situations where farmers have a strong common interest and can benefit from working together, for example in the procurement of inputs or the management of shared natural resources.

One-stop aqua shops

Farmer groups can also be linked to structures that facilitate sharing of experience or access to outside knowledge. Research reported in academic journals, often in English, is an

[1] These and guidelines on conducting IASs are available for download from the STREAM website at: http://www.streaminitiative.org/Library/Communications/communications.html.

important step to sharing new aquaculture knowledge and technology but has little development impact in itself. As a consequence there is increasing interest in "Research into Use" programmes. A particular communications and learning challenge is the exchange of learning with and among poor people who farm in rural areas.

The evolution of local-level institutions that facilitate learning and planning and the availability of accessible local language media are helping farmers to draw down the information and other support services they need and even beginning to provide a platform for policy debate and monitoring and evaluation from farmers' perspectives.

NACA has established nine "'One-Stop-Aqua-Shops" (OAS) in eastern India, one in Pakistan and one in Viet Nam to provide local-level support. The OAS function under the guiding principle of a single-point, under-one-roof provision of services, but are managed by different groups such as NGOs and federations of Self-Help Groups (SHGs), farmer groups and local community officials. The OAS provide a variety of services according to local demand including information, training, fish fingerlings, and access to sources of micro-credit and loans necessary to enter into farming. Previously farmers had struggled and engaged in considerable travel to gain access to resources such as quality fish seed and market information and had often been unaware of governmental, inter-governmental and NGO support, and rural banking services.

To support these facilities, in particular with the media required to fulfill their communications role, NACA/STREAM responded with the launch of OASIS (the "One-Stop Aqua Shop Information Service"). OASIS, like the OAS concept, intends to support changes to the way that information is made available to farmers and through the OAS network offer the following services to:

- offer farmers aquaculture and improved service delivery orientated Better-Practice Guidelines;
- enable farmers to learn from each other's experiences and share these with other primary stakeholders throughout the Asia-Pacific through publications made available in local languages at OASs;
- find out who is who from a "contacts" database, including details of OASs, banks, departments of fisheries, NGOs, SHGs, insurance providers and input suppliers;
- enable farmers to gain access to information and facilitated access to web resources such as the STREAM and NACA Virtual Libraries;
- enable farmers to ask aquaculture-related questions and receive feedback via the NACA web-based "discussion forum";
- offer awareness raising in aquaculture through documentaries, videos and drama; and
- offer exchange visits with successful aquaculture operations within the local area.

OASIS aims to make available information from farmers and fishers, service providers, news agencies, the Internet, academia (including databases of research and outputs from specific research programmes) and on-line communities of shared-interest groups, as well as learning from other countries.

The OAS has become a focus of improved service provision in an age where previously unprecedented levels of communication are possible and has changed the way that information is being made available. The OAS enables service providers to get "closer" to communities through the development of information and service focal points.

Cooperative research networks

Cooperative research networks have gained favour over the last decade as an effective mechanism to leverage limited scientific resources against common problems, fast-tracking technological development while reducing duplication of effort. NACA coordinates one such network, the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN).

APMFAN links researchers and institutions working on marine finfish aquaculture throughout the NACA network. The primary mechanism for information exchange is a regular email newsletter and digital magazine (PDF format) that carries a summary of the latest research findings contributed by participants or collated by the secretariat, links to relevant websites and downloadable publications and contact information. The network conducts periodic workshops and also serves as a vehicle for convening training courses such as the Regional Grouper Hatchery Production Training Course offered by Indonesian research centers and the development of proposals for regional research projects.

Factors contributing to the success of APMFAN have been its focus on a suite of technical problems common to the region (i.e. bottlenecks in reproduction, larviculture, nutrition and health management of marine fish), a regular and common means of communication and exchange, and the presence of a dedicated coordinator to drive network activities.

As many of the scientists and institutions participating in the Marine Finfish Aquaculture Network are also engaged in other forms of mariculture, there may be scope to expand the focus of the network to include other mariculture activities.

The internet

The Internet is the most powerful network for exchanging information that has ever existed in human society. Its scope of coverage, accessibility and influence grow every day. With recent advances in personal web publishing technology and content management systems, it is now possible even for a small organization with a shoestring budget and limited information technology (IT) capabilities to establish an effective website with a global reach. With careful planning, web publishing offers:

- massively improved accessibility and circulation of information and publications (The sheer scale and worldwide nature of the Internet means that even the simplest of web pages can be a highly effective communication tool);
- low publishing costs (good web publishing tools are available for free and most of the costs are fixed; the web offers the opportunity to publish information that may not otherwise be able to be made available in any form);
- fast publishing (it is often possible to publish a new document and inform people of its availability in only a few minutes, making “real time” reporting possible, as well as the provision of time-sensitive services such as market information); and
- community participation (many web-based digital publishing tools are designed to be interactive, allowing groups of people to communicate and collaborate in the process of creating and publishing information via the Internet; this allows the publishing process to be decentralized, giving the creators of the content more ownership of the process).

There are, of course, limitations to using Internet as a mechanism for technology transfer:

- The Internet is not accessible to everyone (in most cases it is useful only to the subset of people that have access to the Internet and/or computers, which tends to be relatively low in rural areas and among farming communities, although in terms of absolute numbers this group can be very large; internet usage tends to be better in the public/research sectors); and
- Some degree of computer literacy is required to make effective use of a digital publishing system and deal with daily security issues such as viruses, and a somewhat higher level to plan, install and administer such a system (these skills are often limited or unavailable in public-sector organizations involved in aquaculture).

The value of digital publishing as a mechanism for technology transfer depends to a large extent on the nature of target stakeholder groups. In most situations it is best seen as a suite of additional tools for communicating with people that should be used in concert with other media, preferably through an integrated communications strategy tailored to meet their needs (for example, as determined through an information access survey).

E-mail newsletters

E-mail is probably the simplest, most ubiquitous and widely understood Internet technology, and email newsletters can provide a personal and highly effective way to link relevant stakeholder groups. The Asia-Pacific Marine Finfish Aquaculture Network has published a regular email newsletter since 1998, as a mechanism for researchers to publish their research findings and share experience. The newsletter contains hyperlinks to relevant web pages, publications and other information resources.

Online communities

Community websites take the web publishing concept one step further by allowing members of the public to participate as well. Instead of merely presenting information to people, community websites allow their members to communicate and exchange information among themselves. The most common form of community website is a "discussion forum", but the community concept can be applied to nearly any form of Web site.

Online communities are a unique tool in that they allow an individual to access the collective knowledge of a large group of people that may be scattered all over the world. They provide a "venue" where people with similar interests can "meet" each other, share experiences and solve common problems. One of the most powerful applications of online communities is a "self-help" group. In a highly decentralized environment, empowering stakeholders to help each other through a community website may be more practical than trying to provide direct assistance to them on an individual basis.

As with other Internet technologies, online communities are only useful to a subset of most stakeholder groups. They must reach a critical mass of participants in order to become effective tools for technical exchange. Once activity reaches a certain level, the feedback and mutual interaction among members becomes largely self-sustaining. Achieving the critical mass of members needed to initiate an ongoing "conversation" can be difficult. The most important aspect is to identify an area of common interest to target stakeholders that will bind them together as a social group.

NACA is piloting the development of an online community on the NACA website, www.enaca.org. The community is still in the early stages of formation, although it has attracted more than 2 000 members to date. The community is open to public participation, but there is considerable potential to make use of the facilities to support research networks (a dedicated marine finfish aquaculture forum is available). NACA is also engaged in training staff from network institutions in website administration and management, with a view to building the capacity of member countries to provide online services and to train their own staff.

PRESENT MARICULTURE TRAINING ACTIVITIES AND LIKELY FUTURE REQUIREMENTS

Regular training activities

There are currently few short-term mariculture training activities that are held on a regular basis, and most are aimed at the national or local level. The available courses are summarized below (the country reports give more detail on national-level training activities):

- *Regional grouper hatchery production training course.* A three-week course organized annually since 2002 by Indonesia and NACA, it has been hosted at both the Gondol Research Institute for Mariculture and the Brackish Water Aquaculture Development Center at Situbondo. The course covers all aspects of broodstock management, captive reproduction, larviculture, nutrition, health management and grow-out. It is a paid course.
- *Principles of health management in aquaculture.* A 19-week online training course convened by the Southeast Asian Fisheries Development Center (SEAFDEC) Aquaculture Department in the Philippines. The course covers disease prevention, diagnosis and management for finfish and crustaceans. It is a paid course.
- The Malaysian Department of Fisheries offers six training courses relevant to mariculture through the Institute of Marine Aquaculture (Kedah) and the Marine Finfish Production and Research Centre (Trengganu). These are aimed at the national level, but may be open to international participation through the Malaysia Government Technical Cooperation Programme. The courses are:
  - *Fundamental aquaculture practice* (7 days).
  - *Seed production and management of marine finfish* (30 days).
  - *Cage culture of brackish water finfish* (5 days).
  - *Feed formulation and preparation at farm scale* (3 days).
  - *Seed production and culture of oysters* (30 days).
  - *Seed production and culture of mussel* (14 days).
- *Marine hatchery management*. A one-year vocational course offered by the Fremantle Maritime Centre (Australia). The course covers general management of recirculating hatchery systems, live food production and health management. It is a paid course.

Other ongoing training initiatives include:

- The Yellow Sea Fisheries Research Institute plans to conduct training courses on the introduction of Hazard Analysis and Critical Control Point (HACCP) management systems, European Union (EU) Food Safety and Sanitation Regulations and Directives on the mariculture of shellfish (particularly on assessing water quality and safety), the implementation of harvesting area classification systems and implementation of marine biotoxin/algal bloom monitoring systems and information on EU markets and entry requirements for Chinese products.
- Thailand has established a programme on food safety for fisheries production aimed at assisting producers to meet requirements for domestic and export markets. The programme targets farmers, government officers and other stakeholders.
- Thailand provides training to around 25 000 farmers and other interested people each year through short courses on aquaculture, breeding and nursing, home-made feeds, health management and value-adding of fisheries products. Demonstration sites are also established in selected fishing communities that provide technical assistance in water analysis and health management.
- The Marine Aquaculture Development Centre at Lombok, Indonesia is conducting training on abalone culture for vocational school teachers from seven provinces, to accelerate spat production and support industry development.
- The Republic of Korea has introduced programmes to assist people (in particular, youth) to study mariculture and to establish aquaculture businesses, to encourage new entrants into the industry.
- The Busan Fisheries Technology Institute, Republic of Korea, has established test farms for the clam *Meretrix lusoria* in four locations around Buan. This included resource management and development of value-added products.

- The Indian Central Marine Fisheries Research Institute has established open sea cage demonstration farms at four sites, two on the east coast and two on the west coast of India.

Potential training activities/training providers

Some research centers in the region have indicated that they have either recently held or have the capability to provide ad-hoc training courses in particular aspects of mariculture in response to requests, as summarized below:

Freemantle Maritime Centre (Australia)
- culture of specific temperate species of marine finfish through short course training programmes;
- aquaculture mechanics;
- water quality analysis and environmental impact assessment of aquaculture.

Central Marine Fisheries Research Institute (India)
- pearl production;
- bivalve hatchery design and management;
- mussel culture;
- edible oyster culture;
- live feed and phytoplankton culture;
- seaweed culture.

National Bureau of Fish Genetic Resources (India)
- cryopreservation of fish milt;
- genetic characterization using isozyme and isoelectric focusing markers.

Brackish Water Aquaculture Development Center (Jepara, Indonesia)
- milkfish hatchery production;
- nutrition.

Center for Marine Aquaculture Development (Lampung, Indonesia)
- breeding and culture of marine finfish (Asian seabass, various groupers, seahorse);
- breeding and culture of sea cucumber;
- breeding and culture of pearl oyster;
- seaweed culture;
- fish health management;
- live food production.

Wando Maritime and Fisheries Office (Democratic People's Republic of Korea)
- laver reproduction.

Pohang Regional Maritime Affairs and Fisheries Office (Democratic People's Republic of Korea)
- polyculture of Japanese flounder and abalone in land-based tanks;
- production of the sea squirt (ascidian) *Halocynthia roretzi.*

National Aquaculture Development Authority (Sri Lanka)
- community-oriented shellfish farming.

Thailand (institute not identified)
- Babylon snail production;
- development of information technology for fisheries.

Future training needs

Recent requests for training related to mariculture as identified in the country review papers, the eighth NACA Technical Advisory Committee Meeting in the Islamic Republic of Iran (November 2005) and the seventeenth NACA Governing Council (February 2006) and by a range of other stakeholders were:

- training opportunities for extension officers in mariculture technology (Cambodia, China, India, Thailand) including livelihoods approaches and communications skills (Cambodia) so as to more effectively support the industry;
- training of extension officers in BMPs in various fields of mariculture;
- extension of broodstock management programmes and improved nursery techniques to prevent genetic deterioration of broodstock, to lay the foundation for future genetic improvement programmes and to assist in providing high-quality seed to farmers (China, Malaysia);
- good handling and storage of fisheries products (China);
- depuration and traceability of shellfish products and enforcement of EU hygiene regulations (China);
- fish health management (Islamic Republic of Iran), disease surveillance and reporting (India);
- marine ornamental fish culture (Sri Lanka);
- seaweed culture (Cambodia, Indonesia, Islamic Republic of Iran);
- aquaculture project development and management; and
- economic and financial planning of aquaculture (Secretariat of the Pacific Community, SPC) (future efforts by SPC will provide tools and training, such as software tools to assist businesses in addressing these areas).

Although some of these issues may be addressed by existing training programmes, further emphasis may be warranted in these areas. Other common issues were:

- poor linkage between research institutes, extension stations and farmers (it is often the interface between different classes of stakeholders that is the most serious problem, for example, between farmers and researchers); and
- a shortage of training opportunities/facilities for youth (new entrants to the industry), farmers and entrepreneurs (India, Islamic Republic of Iran, the Democratic People's Republic of Korea).

CONCLUSIONS

Mariculture is, in general, at an earlier stage of development and technically more complex than freshwater aquaculture. The weakest links in the transfer of technology are often the interface between different stakeholders, for example between researchers and farmers, leading to a considerable delay in the implementation of technological advances by producers and a shortage of skilled labour at the farm level, particularly among small-scale farmers. Development of a whole-of-chain approach to technology transfer will require a hybrid approach that takes into account the needs and behaviour of different stakeholder groups and mechanisms to facilitate interaction between them.

Given the ongoing decline of traditional extension services, there is a need to investigate alternative approaches to technology transfer, including the role of the private sector. Approaches that encourage networking between and within stakeholder groups may offer effective solutions. Collaborative research networks communicating via email and the Internet are an effective mechanism for accessing research resources and exchanging experience in the international context. Farmer associations and locally owned/maintained information centers can offer an excellent and sustainable mechanism for facilitating rapid technology transfer at the local level.

Regional review on existing major mariculture species and farming technologies

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INTRODUCTION

For the purposes of this review, "mariculture" is regarded as aquaculture of aquatic plants and animals that is undertaken in the sea. It thus excludes land-based aquaculture, particularly pond culture. However, because much pond production is classified as "mariculture" in the Food and Agriculture Organization of the United Nations (FAO) statistics, it is difficult to get an accurate estimate of mariculture production in the Asia-Pacific region.

Taking the FAO data at face value, mariculture production in the Asia-Pacific region has grown from around 14.6 million tonnes in 1995 to around 26 million tonnes in 2003 (Table 1). Total value was in excess of US$21 billion in 2003.

STATUS OF FARMING OF SELECTED SPECIES

This paper provides an overview of mariculture in the Asia-Pacific region. A feature of mariculture in the region is that it is exceptionally biodiverse, particularly in comparison with European mariculture, which relies on large-scale production of relatively few species. Because of this and the rapidly changing nature of mariculture development in the region, it is difficult to undertake a detailed review of mariculture production at the specific level. Numerous species and commodity-group reviews have been undertaken in the past few years, and others are in preparation or nearing completion. In particular, the CABI Aquaculture Compendium[1] and the FAO species profiles[2] will provide useful summary data on the status of a range of farmed species. Rather than dealing at the specific level, this paper seeks to assess some overall issues and constraints to the development of sustainable mariculture in the Asia-Pacific region.

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1 www.cabi.org/compendia/ac/
2 www.fao.org/figis/servlet/static?dom=root&xml=aquaculture/cultured_search.xml

TABLE 1

Aquaculture production (tonnes) and 2003 farm-gate value (US$m) for mariculture in the Asia-Pacific region. FAO data for Asia and Oceania, all species, all areas, mariculture only (Source: FAO, 2005b)

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	Value (US$m)
Australia	11 986	13 026	14 023	12 361	14 282	14 442	16 202	16 623	16 274	111
Bahrain	4	3	<0.5	1	3	12	<0.5	3	3	0
Cambodia	731	600	266	197	62	20	3 643	3 703	7 890	2
China	10 532 257	11 130 139	11 560 831	13 709 720	15 653 607	17 056 852	17 955 781	19 251 707	20 400 270	15 296
China, Hong Kong SAR	3 114	3 318	3 310	1 539	1 552	2 172	3 078	2 313	2 742	20
Cyprus	354	682	864	1 078	1 356	1 800	1 800	1 782	1 731	11
Fiji Islands	<0.5	<0.5	<0.5	210	2 925	1 936	1 736	80	25	0
French Polynesia	16	24	52	51	46	51	63	57	57	1
Guam	20	22	22	22	25	25	25	25	.	.
India	8	9	38	212	1 253	1 253	1 253	.	.	.
Indonesia	102 000	148 000	115 000	117 210	135 969	207 814	221 010	234 857	249 225	120
Israel	930	699	1 593	1 902	2 408	2 914	3 161	3 056	3 359	18
Japan	1 314 490	1 276 380	1 272 630	1 226 789	1 252 719	1 230 753	1 255 336	1 333 051	1 277 085	3 947
Kiribati	5 248	9 480	7 376	5 938	9 396	11 174	9 264	4 248	3 904	0
Korea DPR	732 917	779 421	485 791	478 000	478 000	464 000	504 295	504 295	504 295	283
Korea Rep.	996 889	874 797	1 015 334	776 631	766 182	654 440	655 852	781 519	826 245	979
Kuwait	90	90	154	150	176	346	179	179	179	1
Malaysia	101 080	73 002	60 306	82 841	101 721	91 822	96 823	103 617	97 896	18
FS Micronesia	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Myanmar	1 143	1 796	2 123	2 392	4 936	4 964	5 473	6 550	19 181	77
New Caledonia	939	1 061	1 152	1 596	1 850	1 761	1 887	1 911	1 775	14
New Zealand	70 191	74 600	76 700	93 500	91 350	85 185	75 387	86 583	84 642	247
Oman	0	0	0	13	<0.5	<0.5	<0.5	<0.5	344	2
Pakistan	48	57	64	69	76	85	.	72	69	0
Palau	3	2	2	1	1	2	2	4	4	0
Philippines	605 864	691 193	683 343	722 009	735 537	747 414	828 670	936 853	1 039 083	92
Qatar	0	1	2	<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5
Samoa	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

TABLE 1
Continued

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	Value (US$m)
Saudi Arabia	201	201	830	1 758	1 898	2 003	4 212	4 695	9 209	69
Singapore	3 554	3 459	3 942	3 304	3 393	4 397	3 702	4 304	4 371	7
Solomon Islands	13	13	13	13	13	15	15	.	.	
Taiwan PC	33 237	34 889	31 354	26 035	24 034	28 281	26 982	29 037	33 507	113
Thailand	92 833	80 183	66 408	106 155	158 247	147 972	145 300	145 300	145 200	39
Tonga	.	.	.	.	.	.	.	.	3	0
Turkey	8 494	15 241	18 150	23 410	25 230	35 646	29 730	26 868	39 726	181
Tuvalu	.	.	.	.	.	.	.	.	5	0
United Arab Emirates	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2 300	7
Viet Nam	21 320	19 651	29 578	33 270	43 629	55 000	70 000	100 000	130 000	115
Total	14 639 974	15 232 039	15 451 251	17 428 377	19 511 876	20 854 551	21 920 862	23 583 292	24 900 599	21 770

Marine finfish

Marine finfish aquaculture is well established in the Asia-Pacific region and is growing rapidly. A wide range of species are cultivated, and the diversity of culture is also steadily increasing.

Japanese amberjack (*Seriola quinqueradiata*) makes up 17 percent of marine finfish production in Asia, with just under 160 000 tonnes produced in 2003 (FAO, 2005b). Nearly all of this production comes from Japan, where production levels have been relatively stable at 140 000–170 000 tonnes per annum since the 1980s. Other carangids that are becoming popular for culture are the snub-nosed pompano (*Trachinotus blochii*) and silver pomfret (*Pampus argenteus*).

Seabreams are a mainstay of Asian finfish mariculture production, and a range of species are currently cultured.

Barramundi or Asian seabass (*Lates calcarifer*) is cultured in both brackishwater and mariculture environments, though most production is from brackishwater. Global production has been relatively constant over the past ten years at around 20 000–26 000 tonnes per annum, although production has decreased in Asia and increased in Australia over this time.

Grouper culture is expanding rapidly in Asia, driven by high prices in the live fish markets of Hong Kong SAR and the People's Republic of China, and the decreasing availability of wild-caught product due to overfishing (Sadovy *et al.*, 2003).

Southern bluefin tuna (*Thunnus maccoyii*) is cultured in Australia using wild-caught juveniles. Although production of this species is relatively small (3 500–4 000 tonnes per annum in 2001–2003), it brings very high prices in the Japanese market and thus supports a highly lucrative local industry in South Australia (Ottolenghi *et al.*, 2004). The 2003 production of 3 500 tonnes was valued at US$65 million (FAO, 2005b).

Cobia (*Rachycentron canadum*) is a species that is engendering much interest for tropical marine finfish aquaculture. Most production currently comes from China PR and Taiwan Province of China, totaling around 20 000 tonnes in 2003 (FAO, 2005b). However, production of this fast-growing (to 6 kg in the first year) species is set to expand rapidly, not only in Asia but also in the Americas. Cobia is set to become a global commodity, in the same way that salmon has become a global commodity in temperate aquaculture.

Milkfish (*Chanos chanos*) has a long tradition of aquaculture in the Philippines, where it is an important food item. Indonesia is a major producer of seed, much of this coming from "backyard" or small-scale hatcheries, but a significant proportion of the milkfish produced in Indonesia is used for bait by the Japanese tuna fishery. There are traditions of milkfish culture in some Pacific Islands, including Kiribati, Nauru, Palau and the Cook Islands. Although most milkfish culture is undertaken in brackishwater ponds, there is increasing production from intensive mariculture cages where the fish are fed pellets or trash fish.

Seedstock production

Hatcheries are producing greater numbers and a wider range of marine finfish species, but the industry is still heavily reliant on capture of fingerlings for grow-out, particularly for species that are difficult or costly to raise in hatcheries, such as grouper or Napoleon wrasse (Sadovy, 2000; Estudillo and Duray, 2003) or for which there is no established hatchery technology, such as tunas (Ottolenghi *et al.,* 2004). In general, the availability of seed from wild sources is in decline through over-fishing and habitat destruction (Sadovy, 2000; Ottolenghi *et al.*, 2004). Consequently, there is a need to develop sustainable technologies for seed production, particularly hatchery production.

Hatcheries range in size and technology. In Asia there has been considerable development of small-scale or backyard hatcheries that have only a couple of larval rearing tanks. These hatcheries use basic but effective techniques to produce large numbers of seedstock of a range of marine finfish species. Traditionally, much of their production has been of milkfish, but production is diversifying to include more difficult to rear species such as groupers (Sim *et al.*, 2005a).

At the other end of the spectrum are the large technology-dependent hatchery systems that have been developed in Australia and Japan. Much of the hatchery technology in use in Australia has been adopted from Europe and modified to meet local conditions (Battaglene and Kolkovski, 2005). A major focus in developing hatchery technology in Australia in particular is the need to reduce labour inputs because of high labour costs.

Taiwan PC has established itself as a major seedstock production centre for the Asia-Pacific region, with around 1 000 farms involved in producing fry and juvenile marine finfish (Kao, 2004; Su, 2005). Marine finfish production in Taiwan PC is typified by highly specialized production sectors: e.g. one farm may produce eggs from captive broodstock, a second will rear the eggs, a third may rear the juveniles through a nursery phase (to 3–6 cm TL) and a fourth will grow the fish to market size (Liao, Su and Chang, 1994; Kao, 2004).

Nursery

There is substantial mortality of juvenile seedstock captured from the wild (Estudillo and Duray, 2003). Cannibalism among hatchery-reared juveniles is a major cause of losses in many species. Transportation of fingerlings also results in losses (Ottolenghi *et al.*, 2004).

Grow-out technology

Grow-out technology employed in the Asia-Pacific region ranges from small floating or fixed cages used by small family-run operations, to extremely large cages (15x15x15 m) used for amberjack grow-out in Japan or 30–50 m diameter circular cages used for southern bluefin tuna grow-out in Australia (Ottolenghi *et al.*, 2004; Rimmer, McBridge and Williams, 2004).

Much of the marine finfish aquaculture production in the Asia-Pacific region is from small to medium-scale farms. Many farms use relatively simple technologies, with wooden or bamboo cages and plastic barrels or polystyrene blocks to provide buoyancy. However, Japan and Australia in particular use larger and more sophisticated cage systems. In the case of Australia, these are based on European technologies.

The traditional Asian cage system is suited to sheltered inshore waters. As coastal sites have become increasingly crowded, several countries have begun to adopt cage designs that can withstand more open water. These offshore cages have been based on Japanese and European designs. The ability to site farms in more open water has opened up more coastal area for farming.

A major issue regarding the continued proliferation of marine finfish aquaculture in the Asia-Pacific region is the environmental impact of such operations. Although there is now a good understanding of the environmental impacts of cage aquaculture in temperate environments, there has been relatively little work done in tropical systems. This issue is discussed further below.

Crustaceans

Although there is substantial production of marine shrimps in the Asia-Pacific region, effectively all of this production is undertaken in coastal ponds and thus does not meet the definition of "mariculture" given above. There has been some experimental culture of shrimp in cages in the Pacific (Y. Harache, personal communication), but this has not yet been commercially implemented. Similarly, most crab aquaculture is carried out in coastal ponds and does not meet the definition of mariculture used here.

Tropical spiny rock lobsters (Family Panuliridae), and particularly the ornate lobster (*Panulirus ornatus*), are cultured in Southeast Asia, with the bulk of production in Viet Nam and the Philippines. Lobster aquaculture in Viet Nam produces about 1 500 tonnes valued at around US$40 million per annum (Tuan and Mao, 2004).

Tropical spiny rock lobsters are cultured in cages. In Viet Nam, fixed, floating and submerged netcages are used, the former in shallow sheltered areas where the cages can be fixed to the substrate. Submerged cages are mainly used for nursing juvenile lobsters and are located in shallow water. A feeding pipe allows feed to be dropped into the cage, and limits the depth at which this system can be used. Floating cages may be used in depths up to 20 m (Tuan and Mao, 2004).

Seedstock is obtained from the wild. In Viet Nam, coconut logs are drilled with holes to provide an artificial substrate for puerulus/juvenile settlement. Once settled, the juveniles are removed from the logs and placed in nursery cages.

Lobsters are fed exclusively on fresh fish and shellfish, using about 70 percent fish and 30 percent shellfish. Vietnamese farmers show a strong preference for lizardfish (*Saurida* spp.) as a feed item and are willing to pay a higher price for these fish. Juvenile lobsters are fed with chopped fish 3–4 times per day. Larger lobsters are fed 1–2 times per day and fish is fed whole. The food conversion ratio (FCR) for lobsters fed this diet (fresh weight basis) is around 17–30:1 (Arcenal, 2004;, Tuan and Mao, 2004).

In the Philippines, the preferred size at stocking is 100–300 g, and it takes 6–15 months for the lobsters to grow to the optimum size of 0.8–1.3 kg (Arcenal, 2004). Survival is around 90 percent, although stocking smaller lobsters (30–80 g) reduces survival to less than 50 percent (Arcenal, 2004). In Viet Nam it takes 18–20 months to culture juveniles (1–2 g) to the preferred harvest size of about 1 kg (Tuan and Mao 2004).

Although *P. ornatus* is a hardy species, there have been several recorded diseases associated with the use of poor quality seedstock in Viet Nam. These include the bacteria *Aeromonas hydrophyla* and *Proteus rettgeri,* the fungi *Fusarium solari* and *Lagenidium* sp. and*l. Zoothamniun* and *Vorticella* (Tuan and Mao, 2004).

Mariculture of tropical spiny rock lobster in Viet Nam is highly profitable, yielding a profit margin of 50 percent (based on a farm-gate price of US$26.75/kg). More than 4 000 farmers/households are involved in lobster farming in Viet Nam, so it makes an important contribution to coastal communities where it is practiced (Tuan and Mao, 2004). In contrast, farm gate prices for lobster in the Philippines are much lower, US$12–15 per kg, which limits profitability (Arcenal, 2004).

As seedstock supply is limited and likely to remain so in the short to medium-term, and demand remains strong, farming of tropical spiny rock lobsters is likely to remain highly profitable for the foreseeable future. To enhance the sustainability of the industry, there is a need to ensure that seedstock supplies from the wild are conserved to support this valuable mariculture sector. This may be done by setting up marine protected areas specifically to conserve adult breeding stocks of lobsters.

In the medium to long-term, it is necessary to develop hatchery production technology for seedstock for tropical spiny rock lobsters. There is currently considerable research effort on developing larval rearing technologies for tropical spiny rock lobsters in Southeast Asia and Australia.

There is a need to develop less wasteful and less polluting diets to replace the use of fresh fish and shellfish. Other research priorities are to develop improved cage designs, assess the environmental impacts of tropical spiny rock lobster culture and assess the carrying capacity of coastal environments.

Molluscs

Bivalves are a major component of aquaculture production in the Asia-Pacific region. Much of this production is based on the culture of mussel, which is a high-volume, low-value commodity. In the Asia-Pacific region, Thailand and the Philippines are large producers of farmed mussels (Mohan Joseph, 1998; FAO, 2005b), primarily the green mussel (*Perna viridis*) (Lucas, 2003).

At the other end of the spectrum, there has been substantial production of pearl farming, which produces an extremely low-volume but high-value product, cultured pearls.

Despite the fact that hatchery production technologies have been developed for many bivalves, most tropical bivalve culture still relies on collection of seedstock from the wild. Artificial settlement substrates such as bamboo poles, wooden stakes, coconut husks or lengths of frayed rope are used to collect bivalve spat at settlement. The spat may be transferred to other grow-out substrates ("relayed"), or cultured on the settlement substrate (Mohan Joseph, 1998; Lucas, 2003).

There are three major systems commonly used for bivalve culture (Mohan Joseph 1998; Lucas, 2003):

1. Within-particulate substrates – This system is used to culture substrate-inhabiting cockles, clams, etc. Predator-excluding devices, such as mesh covers or fences, may be used.
2. On or just above the bottom – This culture system is commonly used for culture of bivalves that tolerate intertidal exposure, such as oysters and mussels. Rows of wooden or bamboo stakes are arranged horizontally or vertically. Bivalves may also be cultured on racks above the bottom in mesh boxes, mesh baskets, trays and horizontal wooden and asbestos-cement battens.
3. Surface or suspended culture – Bivalves are often cultured on ropes or in containers, suspended from floating rafts or buoyant long-lines.

Management of the cultures involves thinning the bivalves where culture density is too high to support optimal growth and development, checking for and controlling predators, and controlling biofouling (Mohan Joseph, 1998; Lucas, 2003).

Tropical mussels grow to market size (about 5–7 cm shell length) in less than one year, and in many cases 6–7 months, after settlement. Production can reach 1 800 tonnes per ha annually but may be lower in some areas. With a cooked meat yield of around 20 percent, this is equivalent to 360 tonnes of cooked meat per ha per year (Mohan Joseph, 1998). In Asia, farmed mussels are generally sold as whole fresh product. Some products are simply processed, e.g. shucked and sold as fresh or frozen meat. There has been some development of longer-life products, including canned and pickled mussels (Mohan Joseph, 1998).

China and Japan are the largest producers of cultured scallops, with the bulk of production being the yesso scallop (*Pecten yessoensis*) (Lucas, 2003). Production in 2003 exceeded 1.1 million tonnes of yesso scallop (FAO, 2005b). Preferred harvest size (>10 cm shell length) is reached in 2–3 years (Lucas, 2003).

Giant clams (Family Tridacnidae) have been cultured in many Pacific Island countries. Their relatively slow growth rates make tridacnid clams suitable only for extensive aquaculture or stock enhancement. Much of the tridacnid aquaculture production is sold to the marine ornamental market, which provides higher and more rapid returns.

Pearl oysters are farmed in Japan, China, Australia, Indonesia and in several Pacific Island nations, notably French Polynesia and the Cook Islands. Pearl culture is technically intensive, particularly the process of inserting a nucleus to promote formation of a pearl. The period between nucleus insertion and harvest generally ranges between nine months and three years. The quality of the pearl is related to the length of the culture period, but many insertions are unsuccessful, resulting in the death of the pearl oyster or ejection of the nucleus (Lucas, 2003). Pearl oysters are usually grown out using suspended culture systems in which oysters are usually suspended below rafts or on long-lines.

Due to their filter-feeding nature and the environments in which they are grown, edible bivalves are subject to a range of human health concerns, including accumulation of heavy metals, retention of human health bacterial and viral pathogens, and accumulation of toxins responsible for a range of shellfish poisoning syndromes. One option to improve the product quality of bivalves is depuration, which is commonly practiced with temperate mussels, but rarely used in the tropics (Mohan Joseph, 1998; Lucas, 2003).

A major constraint to the development of tropical mussel culture is limited demand and low price (Mohan Joseph, 1998; Lucas, 2003). Although prices are higher in Australia and New Zealand, mussels are still relatively low-priced compared with other seafood commodities. The low economic value of mussels is compensated for by their ease of culture and high productivity (Lucas, 2003). Bioeconomic evaluations of mussel culture in the Philippines indicated a low return on investment for mussel farming, although farming in Thailand and Malaysia compared favourably with other forms of aquaculture (Mohan Joseph, 1998).

Sea cucumbers

The most commonly cultured sea cucumbers are the temperate Japanese sea cucumber (*Apostichopus japonicus*) and the tropical sandfish (*Holothuria scabra*) (Yanagisawa, 1998). Aquaculture production of *H. scabra* is low and is generally still in the experimental phase. However, there is substantial production of *A. japonicus* from both land-based aquaculture and mariculture in China and Japan. Chen (2004) estimated Chinese production of *A. japonicus* in 2003 at 6 335 tonnes, of which 5 865 tonnes (93 percent) were from cultured production and only 470 tonnes from the wild fishery.

Farming of *A. japonicus* is well established in northern China. Most production is from earthen ponds, but there is also some mariculture using sea cages on the substrate or suspended below rafts. The sea cucumbers are fed *Sargassum* and other macroalgae (Chen, 2004; Renbo and Yuan, 2004). In contrast, sea cucumber farming in southern China is only beginning and is likely to utilize the species *Holothuria scabra*, *H. nobilis* and *H. fuscogilva* (Chen, 2004). In Japan juveniles of *A. japonicus* are stocked in coastal waters to replenish local stocks or to develop new harvest fisheries (Yanagisawa, 1998).

In Indonesia, *H. scabra* is farmed in cages of 20x20 m or 40x20 m in shallow (0.75–1.0 m deep) coastal areas or in coastal fish ponds (Tuwo, 2004). Organic material (such as rice bran and animal dust) is added at 0.2–0.5 kg per m^2 every two weeks (Tuwo, 2004). *Holothuria scabra* grow relatively slowly and it takes approximately six months to reach the preferred harvest weight of 200–250 g (Tuwo, 2004). Seedstock supply is mostly from the wild, although there is some hatchery production of juveniles (Tuwo, 2004).

Production technology

Seed production technology for several sea cucumber species is well established in China. Since the 1980s approximately 6–8 billion juvenile *A. japonicus* have been produced (Chen, 2004). In 1994, 2.6 million seeds were produced in Japan (Yanagisawa, 1998).

Techniques for production of *H. scabra* have been developed in India, Indonesia, the Solomon Islands, New Caledonia, Viet Nam and Australia (Purcell, 2004). Tuwo (2004) identified difficulties in accessing suitable broodstock and low rates of survival to juvenile as constraints to hatchery production of *H. scabra* in Indonesia.

Sandfish require large areas for nursery and grow-out phases because growth rapidly becomes limited as density increases (Pitt and Nguyen, 2004). For this reason, there has been considerable focus on their use for sea ranching (Purcell, 2004).

Market

The demand for sea cucumber products, particularly from China, dramatically exceeds supply. Chen (2004) notes that this is because the Chinese view sea cucumber as having medicinal properties, as well as being a delicacy. This high level of demand has pushed the price of *bêche-de-mer* (*A. japonicus*) from RMB 500 per kg in the 1980s, to RMB 600–1 000 per kg during the 1990s, to around RMB 3 000 (approximately US$400) per kg in 2003.

Other invertebrates

Sponges

Sponge aquaculture is generating considerable interest in the research community, but commercial production of farmed sponges in the Asia-Pacific region is low. There is a small commercial farm in Pohnpei (Federated States of Micronesia) and several experimental operations in Australia, New Zealand and the Solomon Islands.

Sponge aquaculture is similar to seaweed culture in that sponges can be propagated vegetatively, and little infrastructure is necessary to establish farms. The harvested product (for bath sponges) can be dried and stored and does not require infrastructure such as refrigeration. Consequently, like seaweed culture, sponge culture may be ideal for remote communities, particularly in the Pacific.

However, the market acceptance and economic viability of commercial sponge farming has not yet been established. Further assessment of basic biological parameters such as growth and survival, as well as development of marketing channels, is necessary before large-scale sponge aquaculture can be developed.

Corals

There has been some small-scale development of coral farming in the Pacific Islands. Both soft and hard corals have been cultured, primarily for the marine aquarium trade, although some hard corals are sold as curios or used for restoration of degraded areas on coral reefs.

Corals are propagated vegetatively. Small pieces of live coral are glued to bases, and these are placed on underwater "tables" fitted with galvanized wire mesh. Growth is reportedly rapid, with aquarium corals reaching harvestable size in 3–12 months.

Because of the low level of capital investment needed and the relatively simple propagation methods used, coral culture is suitable for remote coastal communities where infrastructure may be lacking.

Seaweeds

Aquatic plants are a major production component of mariculture in the Asia-Pacific region. About 13.5 million tonnes of aquatic plants were produced in 2003 (FAO, 2005b). China is the largest producer, producing just less than 10 million tonnes. The dominant cultured species is Japanese kelp (*Laminaria japonica*) (Lüning and Pang, 2003; Tseng and Borowitzka, 2003).

There are around 200 species of seaweed used worldwide, of which around ten species are intensively cultivated, including the brown algae *L. japonica* and *Undaria pinnatifida*, the red algae *Porphyra*, *Eucheuma*, *Kappaphycus* and *Gracilaria*, and the green algae *Monostrema* and *Enteromorpha* (Lüning and Pang, 2003).

Seaweeds are grown for:

- direct consumption, either as food or for medicinal purposes;
- production of the commercially valuable polysaccharides alginate and carrageenan;
- use as fertilizers; and
- feed for other aquaculture commodities, such as abalone and sea urchins.

Production technology

Because cultured seaweeds reproduce vegetatively, seedstock is obtained from cuttings. Grow-out is undertaken using natural substrates, long-lines, rafts, nets, ponds or tanks (Tseng and Borowitzka, 2003).

Production technology for seaweeds is inexpensive and requires only simple equipment. For this reason, seaweed culture is often undertaken in relatively undeveloped areas where infrastructure may limit the development of other aquaculture commodities, for example in Pacific Island atolls. Existing technologies rely on tying individual plants to lines and are time-consuming and limit production (Ask and Azanza, 2002).

Seaweeds are subject to a range of physiological and pathological diseases:

- "green rot" and "white rot", caused by environmental conditions, particularly light levels (Tseng and Borowitzka, 2003);
- "ice-ice" disease in *Eucheuma/Kappaphycus,* associated with low light levels and reduced salinity (Ask and Azanza, 2002);
- epiphytes that compete with cultured seaweeds for nutrients and may block light to the thalli (Ask and Azanza, 2002; Lüning and Pang, 2003); and
- several pathogenic diseases that are associated with infections of bacterial and mycoplasma-like organisms (Tseng and Borowitzka, 2003).

In addition, cultured seaweeds are often consumed by herbivores, particularly sea urchins and herbivorous fish species such as rabbitfish (Family Siganidae) (Ask and Azanza, 2002).

Selective breeding for specific traits has been undertaken in China to improve productivity, increase iodine content and increase thermal tolerance to better meet market demands. More recently, modern genetic manipulation techniques have been used to improve temperature tolerance, increase agar or carrageenan content and increase growth rates. Improved growth and environmental tolerance of cultured strains are generally regarded as priorities for improving production and value of cultured seaweeds in the future (Ask and Azanza, 2002; Tseng and Borowitzka, 2003).

Seaweed aquaculture is well suited for small-scale, household-level business operations run by people living in rural coastal communities. Seaweed fisheries are traditionally the domain of women in many Pacific Island countries, so it is a natural progression for women to be involved in seaweed farming. Seaweed farming in the Philippines is undertaken in some areas where civil disturbances may limit production (Philippines country paper, these proceedings).

PRIORITIES FOR RESEARCH, DEVELOPMENT AND EXTENSION

Mariculture in the Asia-Pacific region is expanding rapidly, and there is widespread concern regarding its sustainability. Priorities for research, development and extension (R,D&E) should be focused on increasing the sustainability of mariculture production.

Seed supply

Seed supply for mariculture comes from two sources: wild populations, where larvae or juveniles are harvested to provide seedstock for grow-out (capture-based aquaculture), and hatchery production of seedstock.

Capture-based aquaculture

Capture-based aquaculture is widely practiced in the Asia-Pacific region, and many seedstock fisheries may be drastically over-exploited (Sadovy, 2000; Ottolenghi *et al.*, 2004). In general, there is a need to move away from capture-based aquaculture to hatchery production to improve the sustainability of these aquaculture sectors.

R,D&E priorities include:

- improved knowledge of biology of relevant species and their fisheries;
- development of specific policies and legal frameworks for capture-based aquaculture that promote interactions between the fishing and farming sectors; and
- spat-fall forecasting for molluscs.

Hatcheries

While hatchery production of seedstock is generally more sustainable than the use of wild seedstock, there remain a range of constraints to widespread adoption of hatchery production.

R,D&E priorities include:

- developing seedstock production technologies to support a wider range of species, including species where seedstock is currently reliant on wild capture;
- controlling and managing disease, particularly viral diseases;
- promoting small-scale hatchery technology to provide livelihood options for marine finfish aquaculture in coastal areas;
- developing more cost-effective larval rearing techniques, such as the use of compounded larval feeds;
- developing new technologies for effective transport of seedstock (finfish fingerlings, bivalve spat) from hatcheries/nurseries to farms; and
- developing and promoting specific pathogen free (SPF) or high health (HH) seedstock.

Genetic issues

Selective breeding has commenced with a wide range of maricultured species. However, the long-term impacts of selective breeding are not well established, particularly for mariculture systems where there is a high risk of selectively bred organisms escaping to interact with wild populations.

R,D&E priorities

- There are indications that inbreeding in some species has led to a decline in seedstock quality. Genetic management protocols are required for hatcheries to prevent inbreeding effects in captive populations.
- There is a need to develop selective breeding programmes for a range of maricultured commodities. Some of the desirable selected traits include: disease resistance, high growth rate, increased thermal tolerance, product colour, and biochemical composition (e.g. carrageenan content in seaweeds).
- There is a need to establish the biodiversity impacts of selectively bred organisms contributing to wild populations.

Production systems

Production systems in many parts of the Asia-Pacific are relatively simple and are ideally suited to small-scale or family aquaculture. However, the trend is for the development of large-scale farms incorporating a range of technologies to improve the cost-efficiency of production. Marine finfish aquaculture in Asia is adopting the technologies used in Europe originally developed for large-scale salmon production. These systems are likely to be more cost-effective for some species (such as cobia) than for others (groupers). However, there is also a need to improve production systems for mollusc and seaweed culture.

Feeds

So-called ”trash” fish (small, low-value or bycatch fish species) are a major source of feed inputs in aquaculture in the Asia-Pacific region. The term “trash” fish is inaccurate in that these fish species would not necessarily otherwise be wasted; alternative uses include reduction to fish sauce for human consumption, use as protein sources for other agricultural commodities (such as pigs and poultry) or even for direct human consumption (New, 1996; Tacon and Barg, 1998; Edwards, Tuan and Allan, 2004; FAO, 2005a).

The issues associated with “trash” fish usage are well documented, most recently in the report of the APFIC Regional Workshop on Low Value and Trash Fish in the

Asia-Pacific Region (FAO, 2005a). Although pellet diets are available for a range of marine finfish as well as some crustaceans, there remain important constraints to the widespread use of compounded diets for aquaculture:

- Farmer acceptance of pellet diets is often low because of the perception that these diets are much more expensive than trash fish. Farmers often do not appreciate that the food conversion ratios of pellet diets (usually 1.2–1.8:1) are dramatically better than that of "trash" fish (usually 5–10:1, but sometimes higher) and so the relative cost of pellet diets is often comparable or lower than the cost of "trash" fish required to produce the same biomass of fish. Variable product quality may also impact substantially on growth and survival of the cultured fish.
- Lack of farmer experience in feeding pellets may result in considerable wastage.
- Fish fed on "trash" fish may not readily convert to a dry pellet diet, resulting in poor acceptance and perceived lack of appetite.
- Distribution channels for pelleted feed are not widely available in rural areas. As well as limiting accessibility to the feed, this factor increases feed costs.
- Many rural areas have no storage facilities. This can result in degradation of the pellets, particularly vitamin content, resulting in poor growth and disease in fed fish.
- Small-scale fishers or farmers operating fish cages may not have access to the financial resources necessary to invest in purchase of pelleted diets or infrastructure such as refrigeration, finding it easier to collect "trash" fish themselves, or obtain it in small amounts as and when financial or "trash" fish resources are available. For many farmers, "trash" fish collection is an opportunity cost that family-operated farms may easily absorb, whereas the purchase of pellets is a cash cost.

R,D&E priorities

- The nutritional requirements of farmed species have to be determined in order to develop cost-effective diets. Research has demonstrated that different species often have different nutritional requirements. Consequently, there will be a range of diets required for various species or species groups. There is a need to define the nutritional requirements of farmed aquatic species, often at the generic or even specific level.
- There is a need for R&D into alternative protein sources for aquafeeds, including terrestrial meat meals and vegetable meals to replace fish protein.
- Changing from "trash" fish to pellet feeds may impact on product quality. The real and perceived impacts of compounded feeds on product taste and texture need to be established in view of consumer preferences. For some species, this may not be important, but this is an issue for high-value marine finfish, e.g. groupers.
- Enhanced information exchange and coordination of nutritional information would benefit the development of compounded aquafeeds.
- Participatory research and extension is a valuable mechanism for promoting the uptake of compounded feeds. The various drivers towards/away from pellet feeds need to be better understood and documented.
- There is a need for feed companies to become actively involved in on-farm trials and to independently evaluate their products. There is no doubt that some batches of pellets perform poorly due to problems with formulation, manufacture or storage. There is a need to work with feed companies to improve product quality and identify areas where improvements can be made.
- National aquaculture development strategies need to incorporate a policy for feeds development.
- There is a need to better quantify the environmental impacts of both "trash" fish and pellet feeds, both in terms of nutrient impacts and as particulate matter

that may cause impacts to benthic communities beneath sea cages. The impacts of feed type need to be integrated with aquaculture planning, farm siting and coastal management.

Environmental impacts of mariculture

Although mariculture production in the Asia-Pacific region includes a substantial quantity of low-trophic-level species such as seaweed and bivalve molluscs, there is a significant production of commodities that require feed inputs, in particular, crustaceans (lobsters) and marine finfish. Environmental impacts associated with marine finfish and lobster cage aquaculture derive mainly from nutrient inputs from uneaten fish feed and fish wastes (Phillips, 1998). For example, studies carried out in China, Hong Kong SAR indicate that 85 percent of phosphorus, 80–88 percent of carbon and 52–95 percent of nitrogen inputs (from "trash" fish) to marine finfish cages may be lost through uneaten food, faecal and urinary wastes (Wu, 1995). These nutrient inputs, although small in comparison with other coastal discharges, may lead to localized water quality degradation and sediment accumulation. In severe cases, this "self pollution" can lead to cage farms exceeding the capacity of the local environment to provide inputs (such as dissolved oxygen) and assimilate wastes, contributing to fish disease outbreaks and undermining sustainability.

However, the impacts of sea-cage aquaculture on coastal waters may be relatively insignificant compared with the terrestrial inputs. In one of the few studies of nutrient impacts of marine cage aquaculture in tropical systems, Alongi *et al.* (2003) found that although fish cages theoretically contributed 32–26 percent of nitrogen and 83–99 percent of phosphorus to the coastal water studied, there was no evidence of large-scale eutrophication due to the cages, and the effects of the cages were largely swamped by large inputs of organic matter from mangrove forests, fishing villages, fish cages, pig farms and other industries within the catchment.

The use of dry pellets rather than wet feeds reduces nutrient inputs through better feed utilization. Other solutions to self-pollution of sea cage sites (Phillips, 1998; Feng *et al.*, 2004) are:

- ensure adoption of better management practices (BMPs), including efficient feed formulation and feeding practices;
- keep stocking densities and cage numbers within the carrying capacity of the local environment;
- use chemicals minimally and responsibly;
- ensure adequate water depth below cages and sufficient water movement to disperse wastes; and
- move cages regularly to allow recovery of the sediments of affected sites.

There is an increasing appreciation of the environmental impacts of mariculture in Southeast Asia, partly because of the worldwide focus on the environmental impacts of Atlantic salmon farming. However, in most countries there is a lack of legislative frameworks and enforcement. Problems can be addressed by more emphasis on local planning initiatives and co-management frameworks, and zoning of coastal areas for marine fish farming. China, Hong Kong SAR provides one example where the government has designated marine fish farming zones; however, critics argue that zoning has allowed too much crowding and caused localized water pollution (Lai, 2002; Sadovy and Lau, 2002). Therefore, zoning of marine fish farming areas has to be accompanied by control measures that limit farm numbers (or fish output or feed inputs) to ensure effluent loads remain within the capacity of the environment to assimilate wastes (Phillips, 1998).

The Philippines is establishing mariculture parks to promote finfish mariculture within a designated area. The park development is controlled by an Executive

Management Council that governs the establishment of "community" mooring systems and clusters of sea cages. This approach attempts to limit uncontrolled development of sea cages, and limit expansion, encroachment and interference with other marine infrastructure (Philippines country paper, these proceedings).

R,D&E priorities

- There is a need for appropriate environmental assessment systems to support site selection and assess the assimilative capacity of the local environment.
- Aquaculture planning and development should be implemented, taking into account other resource users.
- Regulations that limit aquaculture development within appropriate levels should be developed and enforced, and environmental monitoring should be ensured.
- Robust and cost-effective environmental monitoring systems that are appropriate to tropical mariculture need to be developed.
- Improved knowledge of the role of wild fish communities as potential disease vectors and as sinks for excess feed and wastes is needed.
- The fate and impacts of antibiotics and other pharmaceuticals needs to be better understood.

Post-production

Both the supply of, and demand for, aquatic products are changing rapidly in the Asia-Pacific region. While fisheries production is relatively stable, aquaculture production is increasing steadily. The region contains the two largest national populations on the planet: China and India. Demand for quality seafood products is expanding in line with growth in affluence in many parts of Asia. In the light of this rapidly changing environment, the ability to match supply and demand in terms of both quantity and quality of products is critical.

R,D&E priorities

These include the need for:

- improved harvesting and handling techniques to improve product quality;
- improved post-harvest handling, processing, and food safety, including depuration for bivalves;
- development of new products ("value adding");
- development of new market strategies and new market segments; and
- improved market intelligence, particularly to allow farmers to diversify or change production strategies.

Socio-economics

The country papers in these proceedings provide information on the extent of the importance of both coastal aquaculture and mariculture to coastal communities throughout the Asia-Pacific region. However, there is still limited information on how coastal communities will respond to changes in mariculture production trends, such as the trend away from low-input commodities (e.g. seaweeds) to more intensive farming systems (e.g. finfish) in China.

R,D&E priorities

These include the need for better information on:

- the socio-economic impacts of mariculture on coastal communities, both positive and negative;
- the role of mariculture in alleviating poverty in developing countries; and
- the impacts of "urban drift" in rapidly developing economies – many younger

people are looking for employment opportunities in the cities rather than taking traditional roles in sectors such as fisheries and aquaculture (see the Republic of Korea country paper, these proceedings).

POTENTIAL FOR INCREASING THE ROLE OF LOW-TROPHIC-LEVEL SPECIES

There is interest in promoting the cultivation of low-trophic-level marine species to alleviate some of the impacts of culturing animals that require high levels of organic inputs, such as marine finfish. There are two approaches to promoting the cultivation of low-trophic-level species:

- direct replacement of high-input species with low-input species (e.g. replacing production of carnivorous finfish such as (groupers with omnivorous species like milkfish and rabbitfish); and
- promotion of low-trophic-level species that may act as "sinks" for the waste products from high-input aquaculture.

Direct commodity substitution with low-trophic-level species

As noted above, there is already substantial mariculture production of low-trophic-level species in the Asia-Pacific region. Low-trophic-level species include bivalve molluscs, sea cucumbers and seaweeds. Among marine finfish, both milkfish and rabbitfish can be considered low-trophic-level species. Milkfish are cultured throughout the Asia-Pacific region, although most production is from the Philippines and Indonesia, and most of this production is from coastal ponds rather than from mariculture. Rabbitfish are cultured only in small quantities.

One of the drivers against adoption of low-trophic-level species in mariculture is price. Many low-trophic-level species are relatively low-price commodities, the notable exception being sea cucumbers. In China, production of seaweeds has proportionally declined since 1981 because of proportionally greater production of molluscs, shrimps and finfish (Feng *et al.*, 2004). The major reason for this shift is that animal cultivation is more profitable (Feng *et al.*, 2004).

Economic drivers may be important for farmers choosing which species to cultivate. Yap (2002) found that grouper aquaculture in the Philippines was more accessible to farmers than milkfish culture because of higher margins and the lower level of investment required to achieve the same profit.

Cultivation of low-trophic-level species may not necessarily result in environmental benefits. For example, while milkfish can be farmed extensively with negligible feed inputs, this type of culture is generally being replaced with more intensive styles of culture. Cage culture of milkfish relies on the same high levels of inputs as does any other type of marine finfish aquaculture, albeit with lower protein feeds and thus likely lower nitrogen inputs to the environment. The localized environmental impacts from large-scale milkfish culture do not differ substantially from those of any other marine finfish production.

Promotion of low-trophic-level species as nutrient sinks

Many authors have suggested that one solution to high levels of nitrogen inputs from aquaculture is to culture organisms that act as nitrogen sinks, particularly seaweeds (Chopin *et al.*, 2001a; Feng *et al.*, 2004). Most work to date, however, has focused on the use of seaweeds as nutrient sinks in land-based systems (Chopin *et al.*, 2001b; Neori *et al.*, 2004).

Feng *et al.* (2004) noted that 50 tonnes of seaweed can fix 1 250 kg of carbon and 125 kg of nitrogen. Using Wu's (1995) data on finfish effluent fed a diet of "trash" fish and an FCR of 8:1, the nitrogen produced from 1 kg of marine finfish production (4.2–7.6 kg N) would require the absorptive capacity of 1.7–3.0 tonnes of seaweed production. Given the economic drivers away from seaweed production towards more profitable commodities, it is difficult to envisage that large-scale mariculture will incorporate seaweed production at an order of magnitude greater than finfish production.

The dynamic processes that affect utilization of nutrients in tropical mariculture are poorly researched. It is likely that much of the soluble waste from aquaculture production is used up rapidly by bacteria and phytoplankton, and high nutrient levels may not persist far from their source. In this case, there may be limited additional nutrients available for seaweed culture.

An alternative is the use of intermediate organisms to remove phytoplankton that may proliferate because of the nutrient-rich environment adjacent to cages. Pham *et al.* (2004) describe co-culture of green mussels (*Perna viridis*) with tropical rock lobster. Lobsters fed the mussels demonstrated faster growth and better health than those fed "trash" fish. Water quality around cages where mussels were co-cultured with lobsters had reduced concentrations of organic matter in the water column and in the sediment (Pham *et al.*, 2004). The use of filter-feeding bivalves as a nutrient sink that can then be used as a feed source for other cultured species is a potentially valuable option to improve the sustainability of mariculture.

Integrated mariculture

The widespread recognition that aquaculture must improve its environmental performance, both real and perceived, has generated interest in integrated aquaculture. Integrated aquaculture is broadly defined as the culture of a range of trophic-level organisms whereby outputs from one species or group can be utilized as inputs by another species or group. While there has been some research undertaken using land-based systems (Chopin *et al.*, 2001a, 2001b; Neori *et al.*, 2003, 2004; Troell *et al.*, 2003) there has been comparatively little research on "open" or mariculture systems.

While the concept of integrated mariculture is straightforward, there is a paucity of information to assess its effects on the environment. The dynamics of aquaculture-generated nutrients in tropical coastal waters are complex and not well understood. As much of the nutrient input may be absorbed rapidly by phytoplankton and bacteria, the systems used for integrated mariculture may differ substantially from those used in land-based systems, which rely on aquatic plants as nutrient sinks (Neori *et al.*, 2004). With the rapid expansion of mariculture in the Asia-Pacific region, and the need to improve the environmental credentials of mariculture, the topic of environmental impacts and the development of cost-effective amelioration strategies is a high priority.

Better management practices for mariculture

An approach to improving the sustainability of aquaculture has been the development of Better Management Practices (BMPs). To date, BMPs have been most widely used in shrimp culture. More recently, the development of BMPs for mariculture has commenced, particularly with regard to tropical marine finfish aquaculture. The Marine Aquarium Council, together with The Nature Conservancy and with the assistance of the Asia-Pacific Economic Cooperation (APEC) and NACA, has developed Standards for the Live Reef Food Fish Trade, including aquaculture standards. These standards provide a basis for the development of BMP documentation for finfish mariculture.

Two recent publications from the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN) demonstrate the BMP approach to finfish mariculture with respect to the promotion of small-scale marine finfish hatchery technology (Sim *et al.*, 2005a) and the use of compounded feeds instead of "trash" fish to feed groupers (Sim *et al.*, 2005b). These publications are being made widely available in the Asia-Pacific region and have been translated into Thai, Indonesian and Vietnamese to facilitate farmer access to this information. APMFAN plans to expand its range of BMP documentation in future years.

Adoption of BMPs, particularly voluntary adoption, remains problematic. While some BMPs may improve the financial viability of farms, for example through more cost-effective feeds, faster fish growth and improved fish health (Sim *et al.*, 2005b), other BMPs may have associated financial costs that farmers are reluctant to bear (Stanley, 2000). Another issue with regard to adoption of BMPs for mariculture, as noted above, is the paucity of information on the nutrient dynamic processes associated with tropical mariculture. In the absence of detailed research results, it is difficult to develop detailed BMPs, particularly if there are financial costs involved in their adoption.

Different countries in the Asia-Pacific region have BMP or BMP-like information available in a variety of forms. In Australia, there are Codes of Practice for several industry subsectors, including a Harvesting and Processing Code of Practice for barramundi farmers. In the Republic of Korea, the National Fisheries Research and Development Institute publishes culture standards for each aquaculture species (see the Democratic People's Republic of Korea country paper, these proceedings). Information sharing among farmers is supported by the installation of Internet-connected computers in the homes of fish farmers in 100 model fishing villages. Fishermen have access to various information sources, including the ability to communicate through a specialized website (www.badaro21.net) (see the Republic of Korea country paper, these proceedings).

A useful approach would be the development of BMPs, including the coordination and redistribution of existing information, at a regional level. Most of the issues facing mariculture in the Asia-Pacific region are not country-specific, so a coordinated approach would provide consistency and reduce duplication of effort. As the regional organization with responsibility for coordination of aquaculture activities, NACA is ideally placed to direct this coordinated effort.

REGIONAL RESOURCE CENTRES

The following is a provisional list of institutions, derived from country papers presented to these proceedings, that are presented as potential resource centers and sources of expertise for a regional cooperation in mariculture. Identification of additional resources is welcome.

India

Indian Council of Agricultural Research

- Central Marine Fisheries Research Institute, Kochi
- Marine Products Export Development Authority
- Rajiv Ghandi Centre for Aquaculture, Chennai and Port Blair

Indonesia

Directorate-General of Aquaculture, Technical Implementation Units (TIUs)

- Centre For Marine Aquaculture Development, Lampung (Sumatera)
- Marine Aquaculture Development Centre, Batam (Riau)
- Marine Aquaculture Development Centre, Ambon
- Marine Aquaculture Development Centre, Lombok (West Nusa Tenggara)
- Brackish Water Aquaculture Development Centre, Jepara (Central Java)
- Brackish Water Aquaculture Development Centre Takalar (South Sulawesi)
- Brackish Water Aquaculture Development Centre, Situbondo (East Java)
- Brackish Water Aquaculture Development Centre, Aceh

The role of the TIUs is to conduct technology propagation/extension and develop applied technology. Thus they are equipped with commercial-scale experimental facilities (hatchery, nursery and grow-out facilities) training facilities, dormitories and laboratory services.

The technology transfer by these institutions includes:

- on the job training, where the participants stay, learn and work with the staff in charge for a certain period depending on the subject and level;
- publication of posters and leaflets;
- on-farm supervision; and
- pilot projects, prototypes and modelling.

Central Research Institute for Aquaculture

- Gondol Research Institute for Mariculture (Bali)
- Research Institute for Coastal Aquaculture, Maros (Southern Sulawesi)

Islamic Republic of Iran

The Iranian Fisheries Research and Training Organization (www.ifro.org) affiliated to Shilat is the major source of applied research and training on fisheries and aquaculture. It has ten research centers and two training centers:

- four centers that located by the Persian Gulf and Oman Sea, in Khuzestan, Bushehr, Hormozgan and Sistan –Baluchistan provinces;
- five Fisheries Research Centres that are located by the Caspian Sea, in Giulan, Mazandaran and Golestan provinces; the International Institute of Cold Water in Mazandaran and the International Institute of Sturgeon in Guilan; and
- the Artemia Research Centre, located by Urimia Lake (research on *Artemia* and live feed).

Research outcomes are used for running pilot projects that are modified as needed. The results are then extended to farmers through short training courses and manuals.

Republic of Korea

Eighteen fisheries subsidiary organizations, including several branch offices of the Ministry of Maritime Affairs and Fisheries (MOMAF) exist in rural areas, mostly located along the coast. Their role is to support fishermen with information, training and government funding. The major government aquaculture research institutes are the National Fisheries Research Development Institute (NFRDI) and Pukyong National University.

Viet Nam

Resource centers include:

- Research Institute for Aquaculture No.1, Cua Lo and Cat Ba
- Research Institute for Aquaculture No.2, Ho Chi Minh City and Vung Tao
- Research Institute for Aquaculture No.3, Nha Trang
- University of Fisheries, Nha Trang
- Institute of Oceanography, Nha Trang

Malaysia

Resource centers include:

- The Institute of Marine Aquaculture (IAM), Pulau Sayak, Kedah, which opened in 1987. Courses offered include marine finfish seed production, finfish aquaculture in cages, marine shrimp seed and grow-out programme, seed and grow-out production of oyster and mussel, and feed formulation for farm practice.
- The Marine Finfish Production and Research Centre (MFPRC), Tanjung Demong, Besut, Trengganu. Courses are offered on marine finfish fry production and cage- culture operation.

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SECTION 2

Country experiences

Bangladesh

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Kabir, H. 2008. Bangladesh. In A. Lovatelli, M.J. Phillips, J.R. Arthur and K. Yamamoto (eds). FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11 March 2006. *FAO Fisheries Proceedings.* No. 11. Rome, FAO. 2008. pp. 129–132.

AN OVERVIEW OF THE FISHERIES SECTOR

Bangladesh has extensive water resources in the form of numerous small ponds, ditches, lakes, canals, small and large rivers, and estuaries covering approximately 4.34 million ha. The culture fisheries include freshwater ponds of 0.15 million ha and coastal shrimp farms of 0.14 million ha. The country has a coastal area of 2.30 million ha and a coastline of 714 km along the Bay of Bengal supporting a large artisanal and coastal fisheries (Figure 1). In addition, it has a 166 000 km2 of Exclusive Economic Zone (EEZ) in the Bay of Bengal. The fisheries sector of Bangladesh is highly diverse in resource types and species. There are 795 species of fish (including 12 exotic species) and shrimp in fresh and marine waters. Exports were valued at US$307 million in 2003. In 2000 the fisheries sector contributed approximately 6 percent of the national gross domestic product (GDP), including full-time employment equivalent to at least 5.2 million people or 9 percent of the labour force. Moreover, the sector provides a safety net for income and food for the rural poor.

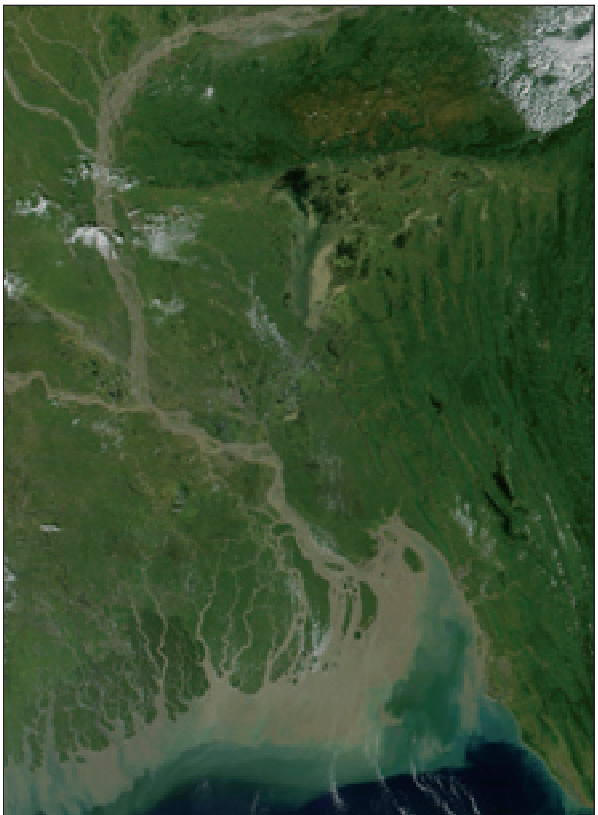

FIGURE 1
Aerial view of the coastal area of Bangladesh

Total production is estimated at 750 000 tonnes from inland capture fisheries, 850 000 tonnes from inland aquaculture and 95 000 tonnes from coastal aquaculture (on-shore aquaculture; the major species include shrimp and a few finfish) and 589 000 tonnes from marine fisheries. Inland and marine capture fisheries are declining annually by approximately 5 and 1 percent, respectively. The current levels of marine fisheries production are being maintained by a significant increase in fishing effort. On the other hand, aquaculture has grown by about 14 percent per annum over the decade. Areas of growth include carp (20 percent per annum) and shrimp (3 percent per annum). Mariculture in the Bay of Bengal is is considered as one area for future development of the production of aquatic animal products.

MARINE RESOURCES

Bangladesh has wide ranging marine biodiversity. There are some 1 093 marine aquatic species recorded in the waters of Bangladesh, of which 44.4 percent are finfish, 32.2 percent shellfish, 15.1 percent seaweeds and 8.32 percent other organisms, including shrimps. Details on the number of species are provided in Table 1.

TABLE 1
Marine aquatic biodiversity in Bangladesh

Aquatic groups	No. of species	Percentage (%)
Finfish	486	44.4
Sharks, Rays, Skates and Dolphin	21	1.9
Shrimps	36	3.3
Lobster	6	2.0
Crabs	16	
Sea turtles	3	0.3
Crocodiles	3	0.3
Squid and Cuttlefish	7	0.6
Shellfish (univalves and bivalves)	350	32.2
Seaweeds	165	15.1
Total	1 093	100

MARINE AQUACULTURE

Bangladesh does not have any marine farming, only land-based coastal aquaculture.

Coastal aquaculture

Coastal aquaculture has developed significantly in the last decade, particularly the culture of shrimp (*Penaeus monodon* and *Litopenaeus indicus*) in medium to high-saline water and prawn (*Macrobrachium* sp.) culture in less saline areas. In addition, there is a small production of mangrove crabs (*Scylla* spp.) and varied quantities of brackishwater and marine fish species such as seabass and mullet, most of which are produced as by-products or during fallow periods in shrimp ponds. Shrimp farming constitutes the major export-oriented subsector of aquaculture. Its relatively high value places considerable importance on upstream inputs such as seed and feeds, and downstream services such as transport and processing.

Seed supply

This subsector comprises both capture and culture elements, supplying both finfish and shrimp seed. Both groups still depend to varying degrees on wild-caught stocks, although fish (carp) culture is increasingly dominated by hatchery supply, and shrimp/prawn culture is steadily increasing its demand for hatchery-bred seed. The supply of wild seed has important interactions with artisanal fishing in coastal areas. Whatever the source of seed, considerable national (and cross-border) networks have been set up to distribute seed. The government has banned the collecting of wild postlarvae from the coastal zone to conserve its biodiversity. This has caused more demand and hence an increasing supply of hatchery-produced seed over the past four years. The transportation systems have been modernized as well. Farmers still depend upon wild-caught seed for finfish such as seabass and mullet.

Post-harvest and market

The gradual shift from local consumption within rural areas, and the growth in urban markets and their service infrastructures, has increased the role of market intermediaries and service suppliers in coastal aquaculture. However, as many markets are still based on wetfish sale, the scope for value addition has been limited. More particularly, the production of shrimp and its export in frozen tailed form have created a significant production subsector, with large commercial investments and notable employment impacts.

In 2001, Bangladesh achieved its highest ever export earnings of US$32 million by exporting 29 719 tonnes of shrimp. The growth in exports has been consistent since the early 1970s, but it was set back by problems associated with health and food safety in 1997–2000.

General support to the subsector

A range of products and services support coastal aquaculture. However, most of the input supply services are relatively under- or undeveloped, such as production of seed, feed, equipment, maintenance and other post-harvest supplies. Positive changes have occurred in the more commercialized subsector of shrimp farming. The provision of research and extension and of financial and management services needs to be further developed and modernized.

Offshore mariculture

Bangladesh has approximately 714 km of coastline and 166 000 km^2 of Exclusive Economic Zone (EEZ) with 1 093 species of aquatic marine organisms including finfish, shellfish, shrimps, seaweeds etc. The marine capture fishery is declining at about 5 percent per annum, so it is the right time to think about how to increase marine production. This situation points to the need to develop mariculture. In the strict sense of the concept, there is no mariculture in Bangladesh. Among the marine species, only shrimp is cultured in on-shore ponds. Other species such as seabass, mullet and mud crab have begun to be cultured in saline-water ponds on a limited scale, and have shown potential for mariculture.

Constraints

The following constraints need to be addressed for the development of mariculture in Bangladesh. The resolution of these constraints would increase marine fish production in a sustainable manner, reduce pressure on wild stocks and have a tremendous and long-term impact on the livelihoods of coastal people. Regional cooperation will be
- essential to deal effectively with the constraints, which include:
- lack of awareness about mariculture techniques, such as cage culture;
- lack of appropriate technology for mariculture;
inadequate infrastructure in relation to information, communication, transportation,
- hatcheries, markets, etc.;
- lack of skilled manpower;
- areas for mariculture not demarcated by the government; and

lack of financing to the sector.

THE WAY FORWARD

Initiatives have to be taken by both the government and the private sector to develop mariculture and the market for mariculture products in a more coordinated way and in collaboration with regional and international organizations. These are geared to:

- Capacity building, including:
  - developing appropriate technologies for mariculture suitable to the climatic, market and socio-economic conditions of Bangladesh;
  - developing knowledge and appropriate technical and management skills for mariculture; and
  - demarcating areas for mariculture (zoning).
- Development of infrastructure, including:
  - roads;
  - educational and training infrastructure and programmes;

  - information and communication systems for rapid access to information; and
  - modernization of market infrastructure, including landing centers and the marketing channels for both inputs and outputs.
- Development of networks, including:
  - producers' organizations and networks for information, better management and access to finance; and
  - coordination with regional and international organizations for updating and accessing technology, markets and other support.

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BACKGROUND

The Chinese population, currently at 1.2 billion people, is predicted to rise to 1.6 billion by 2026, reducing further the per capita share of land resources for food production. Per capita agricultural land has steadily decreased from 0.19 ha in 1949 to 0.076 ha in 2005. These considerations, rapid changes in population structure and rising living standards have presented the Chinese with several challenges and opportunities to meet the rising demand for high-quality animal products, in particular aquatic products. Between 1991 and 2020, the national per capita consumption of fish is projected to increase annually by 5.6 percent (Huang, Rozelle and Rosegrant, 1997). The acknowledgement of stagnating wild fish stocks has focused Chinese fishery development policies on expanding inland, brackish and, in particular, marine aquaculture as a key strategy for meeting changing national demand and consumer patterns.

To meet these rising demands, the People's Republic of China has formulated and refined its aquaculture development policies, targeting specific national, provincial and farm-level issues aimed at transforming the aquaculture sector from a centrally based to a market-based activity. At the national level, the development of inland aquaculture production was part of the strategy for rural industrial development. Freshwater aquaculture expanded from the traditional provinces south of the Huai River into the northeastern, western and northern regions of China.

To increase fish production and employment in the provinces, the area allocated for culture was increased and the types of water bodies approved for aquaculture broadened, attracting hitherto uninterested households, state-owned farms and water conservation departments in many villages and towns into taking up aquaculture as an additional viable economic activity. In 2004 the total fishery (aquaculture and capture) labour force reached 13 million, while the total number of people employed full-time in mariculture and marine capture fisheries was 5.4 million. This increased opportunity played an important role in alleviating rural poverty and increasing the income of farmers.

To address key issues such as pollution, the government has introduced legislation to control water quality in order to protect aquaculture and capture fisheries. Since 1979 more than 500 laws and regulations have been issued by the State Council. For farmers producing high-value species, including small shrimp, eel, mandarin fish etc., fluctuations in fry cost, supply and quality; increased feed, medication and other input costs; price fluctuations of end products and high quality standards for export products have all increased investment risk. To promote sustained production of high-value species, the Chinese government is promoting private investment and the formation of joint ventures with foreign companies that should continue to improve technology transfer and reduce some of the investment risk.

There are more tasks facing China, including:

- restructuring of the entire fisheries sector to improve quality and increase income (not only increase production) to add value to the sector;
- preferential loans, fiscal conditions and improved technical support to operators;
- extension of the use of manufactured feed pellets to reduce eutrophication;
- transformation into a professional industry with producer associations;
- upgrading of the national technological base; and
- strengthening of scientific research, education and training to improve research capability and preparedness for emergencies.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKETS

The AsiaFish Model for fish product

Quantitative modelling of supply, demand and trade for fish becomes very useful for evaluating development strategies and options if done for disaggregated fish types, production categories and regions. With detailed analysis, one can identify priorities in terms of technologies for dissemination, research problems to address, regions on which to focus investments and fish groups that contribute most to food security of the poor. Recently a quantitative tool called the AsiaFish model (Dey, Briones and Ahmed, 2004) has been developed for this purpose. This model is currently being applied to nine major fish producers in Asia (Bangladesh, China, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Viet Nam). The AsiaFish model is a quantitative tool for analyzing the supply and demand outlook and impact of policies, at a disaggregated level, in order to provide detailed guidance on the design of development strategies for the fish sector. The model has been applied to nine major fish producers in Asia with the aim of generating projections to 2020. Our results indicate that, with the rising population and income, fish demand will continue to grow. Supply will also rise, with the bulk of the increase coming from aquaculture.

Generating an outlook for fish in these countries is useful for at least three reasons. Firstly, these countries account for a significant proportion of global production and consumption, contributing over 51 percent of output while absorbing 40 percent of consumption (Delgado *et al.*, 2003). Secondly, the growth performance of the fisheries sectors in these countries has been impressive: between 1991 and 2001, production in these countries grew at an average annual rate of 7.8 percent, more than twice the growth rate of world fish production. Fish consumption in these countries has also been rising rapidly; for example, the growth rate of consumption for China during the period 1985–1997 was 11.8 percent – over triple the global average of 3.3 percent. As argued in Dey, Briones and Ahmed (2004), existing food-sector models are ill-suited for the task of making fish-sector projections for these countries. With few exceptions, these models typically gloss over the heterogeneity of fish types, the presence of alternative production sources (i.e. capture vs. culture) and the diversity of consumption demand across income groups or regions. The AsiaFish model addresses all these difficulties, as well as assorted data problems such as jointness of production and the mismatch of fish type definitions in country-level data on production and consumption.

The AsiaFish model is a multi-market equilibrium model for evaluating the effects of technology and policy changes on the prices, demand, supply and trade of various fish types. It is divided into producer, consumer and trade cores. The consumer and producer cores are essentially two sets of demand and supply equations systems. The producer core distinguishes between fresh and processed fish, with the assumption that a fixed ratio of fresh fish output is allocated to processed fish. Supply of fresh fish is also distinguished by domestic production source. The consumer core of the model describes the behaviour of households, which can be disaggregated by region and/or income class. The demand functions derive from a three-stage budgeting framework. The first stage divides consumption expenditure into food and non-food spending. The second stage determines the representative household's demand for fish as a whole. The final stage captures the demands for different types of fish, using the quadratic form of the Almost Ideal Demand System (AIDS). The trade core of the model is composed of a series of export supply and import demand equations. In the tradition of Applied General Equilibrium (AGE) models, domestic and foreign goods are treated as differentiated products, which is the Armington assumption. One advantage of this formulation is that it allows a fish type to be exported and imported at the same time ("cross-hauling" in the trade data). The aggregation follows a functional form characterized by constant elasticity of transformation (in the case of exports) or constant elasticity of substitution (in the case of imports). Model closure is attained through simultaneous equilibrium among the three cores. The closure condition is, however, considerably complicated by the presence of mismatched fish type definitions in the production and consumption data. To complete the matching, the model identifies demand or supply composites. That is, a demand (supply) composite is one that is matched to several fish types on the supply (demand) side. The model then disaggregates the demand (supply) composite based on a constant elasticity function (in imitation of the Armington technique).

The preliminary results of China from the AsiaFish model are shown in Tables 1–3 below where the cumulative yearly growth rates for a 15-year period are indicated.

TABLE 1
Projected growth of the output of fresh fish, 2005–2020

Value (%)	Quantity (%)	Aquaculture (%)	Capture (%)
6.22	3.04	4.69	-

TABLE 2
Projected growth of fish consumption and consumption per capita, 2005–2020

Consumption			Consumption per capita	
Total (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)
2.53	(2.00)	3.62	0.30	0.98

TABLE 3
Projected growth of fish export and import, 2005–2020

Quantities		Values	
Exports (%)	Imports (%)	Exports (%)	Imports (%)
2.92	1.82	6.69	4.10

A forecasting support system for aquatic products price in China

In China, aquaculture has been the fastest growing subsector within the agricultural economy over the past two decades, enjoying an average annual growth rate of about 10 percent. The growth in the aquaculture subsector has also been accompanied by a significant structural change. The share of cultivated fish in total production has increased substantially, from 25 percent in 1970 to 60 percent in 2000. On the demand side, per capita consumption of fish, which was only 1.2 kg in rural and 3.7 kg in urban areas in 1980, reached 5.8 and 18 kg, respectively, by 2000 (Huang, 2003). In the light of such growth, the aquaculture subsector had become more prominent in the process of agricultural structure adjustment, both in generating an alternative source of income for farmers and in enhancing food security in China. However, the technological advancement in the production and storage of fishery products has exceeded the development of efficient market demand over the past decade.

China has a wealth of data on marketing produced by municipal, county, province, state agency, academy, university and market. Unfortunately the data are scattered among a multitude of producers with dissimilar formats and resolutions. Recently work has been conducted by the Ministry of Agriculture and Ministry of Science and Technology to develop a common database that has yielded some usable consistent results (www.uast.com.cn). To this end, a forecasting support system for aquatics product price (APPFSS) has been developed (Zhang, 2004; Zhang *et al.*, 2005). This computer-based information system combines models, data, expert knowledge and a user interface and supports the aquaculture industry to predict market prices and related information.

The strategy options for trade and market access

The reformed and open environment in China has provided easier conditions for the development of fisheries, a circumstance that included two main policies. The first was the liberalization of the right to land use and farm management. An aquaculture farm management system was adopted based on the household responsibility system as the key element, combined with a diversified operating system. In order to encourage the people to reclaim and exploit low-lying or saline-alkali land suited for aquaculture, the local governments actively established preferential policies and provided support and privileged fiscal and investment measures. These were extremely successful, arousing enthusiasm for involvement in developing aquaculture both within the population and industry. The second policy was the liberalization of price control by the government, which allowed the price of fish products to adjust to the market, permitting a full range of advantages of unified production and sales. These policies have given great impetus to the development of aquaculture in the country. To be able to assure a constant, year-round supply of fresh and live fish, aquaculture methodology was also reformed, including the policy of "take turns in fishing and stocking, catch the bigger and leave the smaller". This approach lessened seasonal peaks and troughs in supplies, thus improving the market situation and reducing overstocking as well as fluctuating prices. It is evident that aquaculture outputs and benefits have been improved with these reforms and operational changes.

Cooperation among individual farmers

Most farms in China are small, which makes it difficult and costly to individually fulfil requirements to ensure product quality. Collectively, however, the speedy delivery of products to processing plants could be assured. It is important that buyers' requirements of safe, clean and quality products are fulfilled and for producers to establish the capability, and therefore reputation, of reliability. Establishing mutually beneficial relations with buyers depends on reliability and trust.

Cooperation among producers

Cooperation among producers would avoid or minimize the risk of a member providing products tainted with banned substances. Lessons could be learned from the experiences of some countries in promoting country-label products and integration between producers and buyers. It was advised that producers should actively promote their products to potential buyers and initiate and sustain dialogue between buyers and producers. The risk or tendency of buyers to use food safety as a pretext to take advantage of the seller could be minimized with timely information on prices and knowledge of pricing mechanisms.

Capacity building for quality assurance

Governments usually invest in the improvement of facilities and develop regulations, but need assistance in training in quality control. Training in Hazard Analysis and Critical Control Point (HACCP) and application of HACCP not only at the plant but also at the farm level would be extremely helpful. Likewise, assistance in the development of codes of practice and guidelines for good management and manufacturing practices is needed.

Cooperation among governments

A common and cohesive stand among Asian governments on issues that impact their aquaculture sector is needed. It would enable the region to maintain its position as a major producer and exporter of aquatic products. Cooperation would enhance competitiveness in the global market and would also facilitate and expand intra-regional trade.

Domestic marketing system

An efficient domestic marketing system would have a strong impact on social objectives, including poverty reduction and food security assurance. A good market infrastructure, better facilities and easier access to information would facilitate domestic trade that would impact positively on rural development by raising technical efficiencies, farmers' incomes and supply of affordable and nutritious aquatic products. Governments usually invest in market infrastructure, although municipal governments now involve the private sector in the management of the markets. An expanding population and its growing affluence, as well as changing population structures are important factors that should be considered in the development of the domestic market.

THE DEMAND FOR FISHERIES AND AQUACULTURE PRODUCTS

Both fish species and fish products will develop in different and diversified directions according to consumers' buying power, consumption habits and perceptions. According to present trends, the consumer appreciates and welcomes nutritious and safe fish products, with particular appreciation for the highly rated species, which represent a considerable development opportunity. These include freshwater species such as mandarin fish, snakehead, perch, catfish, shrimp, softshell turtle and tortoise, while marine species of interest include fish, shrimp, molluscs and seaweed.

The diversity of food preferences gives a wide range of consumption patterns, which is good for both the exploitation and the utilization of natural resources. This contributes to the avoidance of the irrational exploitation of the food chain and environmental destruction and is, therefore, good for the sustainable development of fisheries.

Due consideration has been given to ensure basic fish supplies and improve the food security situation in rural areas. Fish farming is considered the quickest and most effective way to increase fish supplies, and it has been given high priority in the national fisheries development plan in the context of rural development. The government has been extremely supportive to rural aquaculture development through its technical extension service, particularly for the production of species that are low in the food chain, and with a wide adaptability and high productivity.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

Trade figures in aquatic products from FAO Globefish show the importance of aquatic product trade to developing economies. In 2001 the value of global fish exports was US$56 billion, 50 percent of this from developing countries. More significantly, the net export revenues from developing-country fisheries were US$18 billion. The developed countries imported more than 80 percent of world imports in value. The European Union, the United States of America and Japan together imported 77 percent of the total.

The Chinese government seeks to improve the ability of aquaculture farms and their fisheries and aquaculture sectors to access markets. The pathways are greater competitiveness through technical efficiency in production, processing and marketing; compliance to market requirements, including standards; responsibility to consumers, the environment and society; and better capacity to transact with buyers and negotiate in world fora. There is general agreement that fair trade and a well-developed domestic marketing system are a powerful means to reduce poverty and improve food security, reduce dependence on aid, and even serve to attract direct investments, particularly in a technically efficient and competitive seafood production and marketing sector.

Between 1980 and 1998, the additional number of people employed in the fisheries sector was 10 million; the average new entry or job creation is half a million people a year, with 70 percent going into aquaculture. To meet the demands of another 100 million people that are expected to be added to the population in the next 20 years, the fisheries development plan aims to promote the transformation of the fisheries economic system to fit the basic requirements of a market economy, and to promote science, education and sustainable fisheries development. The goal is to increase aquaculture's contribution to improve the welfare of farmers and develop the rural economy.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

In order to bring fishery technical extension into full play, it is necessary to develop different types of services for the benefit of the production sector. These include technical associations, mutual insurance aid and other nongovernmental service organizations (NGOs) that can serve the fisheries and aquaculture sectors. It is also necessary to improve the abilities for self-protection and self-development of the labour force under the conditions of a market economy.

The aspirations for aquaculture development for the period 2005–2020

In the next 15 years, the emphasis of fisheries and aquaculture development in China will be to:

- meet the needs of social and economic development;
- increase the efficiency of fisheries production;
- develop and promote aquaculture, agriculture and the rural economy;
- expand and diversify production so as to meet the demand for fish and fishery products; and
- make the best use of market potential.

To realize these goals, the state will primarily support the development of six core systems and six areas of concern. The systems to be developed are:

- original and fine species diversification system;
- fishery scientific and standardization system;
- fishery technology extension system;
- disease control system;
- fishery marketing system; and
- fishery management and environmental protection system.

The six fields to be developed are the:

- vertical integration of aquaculture production in the fish culture bases;
- offshore and distant-water fishing;
- processing of fish products and comprehensive utilization of materials;
- building of fish ports;
- building of fishing vessels; and
- manufacture of fishery machinery and new technical exploitation.

Present training activities and likely future requirements

In order to transfer the technology of environmental monitoring to promote socio-economic progress and environmental improvements in the aquaculture sector in Shandong Province and further in China, five training courses and workshops were held between 2003 and 2005 in the cities of Beijing, Qingdao and Rizhao. The training courses and workshops, which were organized by the Yellow Sea Fisheries Research Institute focused on the introduction of HACCP management systems and European Union (EU) Food Safety and Sanitation Regulations and Directives on the mariculture of shellfish, especially on the assessment of water quality and safety, the implementation of harvesting area classification systems, the implementation of a marine biotoxin/harmful algal blooms monitoring regime and information about EU markets and how Chinese farmed shellfish products can enter them. Nearly 240 technicians, managers and governmental officials joined the meetings.

Following these training sessions, an additional three training courses were held in 2006 in Shandong Province. The courses focused on the depuration centres and technique, the traceability of shellfish products and the enforcement of EU hygiene legislation, so as to improve environmental and products quality, foster long-term sustainable development of shellfish in China and then find a gateway for Chinese shellfish products into EU markets. Further capacity building will be required in all key areas.

MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

The major mariculture species in China are shown in Table 4.

TABLE 4
Major mariculture species and production (tonnes) in 2004 for selected spaces

Finfish	Bastard halibut *(Paralichthys olivaceus)*		57 270
	Blackfin seabass *(Lateolabrax latus)*		80 625
	Convict grouper *(Epinephelus septemfasciatus)*		33 033
	Black porgy *(Acanthopagrus schlegelii)*		46 248
	Parrotfish *(Oplegnathus fasciatus)*		-
	Red seabream *(Pagrus major)*		-
	Other seabreams		-
	Brown croaker *(Miichthys miiuy)*		-
	Red drum *(Sciaenops ocellatus)*		43 506
	Yellowtail *(Seriola quinqueradiata)*		12 572
	Puffers		14 861
	Korean rockfish *(Sebastes schlegeli)*		-
	Other rockfishes		-
	Mullets *(Mugil* spp.*)*		-
	Okhostk atka mackerel *(Pleurogrammus azonus)*		-
	Konoshiro gizzard shad *(Konosirus punctatus)*		-
	File fishes *(Stephanolepis* sp., *Thamnaconus* sp.*)*		-
	Other finfish		-
		subtotal	**582 566**
Crustaceans	*Fenneropenaeus chinensis*		54 380
	Penaeus japonicus		45 173
		subtotal	**722 172**

TABLE 4
Continued

Shellfish	*Crassostrea gigas*		3 750 910
	Rapana venosa		202 452
	Haliotis discus hannai		-
	Chlamys farreri nipponensis		-
	Cyclina sinensis		2 799 004
	Mactra chinensis		-
	Scapharca subcrenata		323 225
	Solen spp.		676 391
	Ruditapes philippinarum		-
	Meretrix lusoria		-
	Atrina pectinata		-
	Scapharca broughtonii		-
	Mactra veneriformis		-
	Mytilus coruscus		717 368
	Other shellfish		-
		subtotal	**10 247 151**
Seaweeds	*Porphyra* spp.		81 017
	Laminaria japonica		801 128
	Undaria pinnatifida		219 607
	Gelidium amansii		115
	Gigartina spp.		-
	Codium fragile		-
	Hijika fusiforme		-
	Enteromorpha spp.		-
	Other seaweeds		-
		subtotal	**1 467 545**

The major farming technologies are shown in Table 5.

TABLE 5
Aquaculture methods used in China

Commodity		**Culture methods**
Finfish		Land-based tank culture
		Pond culture
		Cage culture
		Other methods
Crustaceans		Pond culture
Shellfish		Hanging culture (scallop, oyster, abalone, mussel, etc.)
		Bottom culture (clam, oyster, abalone, etc.)
		Land-based tank culture (abalone)
Seaweeds		Floating net method
		Longline method
		Other methods
Others:	Sea cucumber	Pond culture
	Polychaetes	Pond culture
	Jellyfish	Pond culture
	Sea urchin	Bottom culture

Polyculture

One possible solution to avoid and lessen aquaculture impacts on the environment is extensive and balanced "polyculture" – an integrated fish-farming practice adopted over 4 000 years ago in China and over 1 500 years ago in Hawaii. Polyculture techniques mix fed species (e.g. finfish, shrimp), herbivorous species and extractive species (filter feeders, such as shellfish, and seaweeds) in a more balanced ecosystem-approach to aquaculture. While polyculture has not been implemented to any great extent, it may offer opportunities for reducing or transferring nutrient loads. Ecosystems are inherent recyclers of energy and can provide the resources humans need as long as critical processes are left undisturbed. Ecosystems, although frequently described as "fragile", have remarkable powers of resiliency. As long as basic processes are not irretrievably upset, ecosystems will continue to recycle and distribute energy. A healthy, functioning ecosystem not only sustains itself, it also sustains local communities, regional economies and resource-based industries, in this case aquaculture. This suggests that strategies and guidelines for sustainable management should focus on maintaining resilience and healthy functioning of coastal and marine ecosystems.

Examples of integrated culture

Some examples of integrated mariculture systems are:

Israel	sea bream + *Ulva* abalone + fish + *Ulva* abalone + fish + bivalve + *Ulva*
China	shrimp + crab + seaweeds (pond culture) mussel + scallop + *Laminaria/Undaria* (longline culture) fish + *Gracilaria* fish + seagrass + *Kappaphycus*, scallops and crab (lantern net culture) seaweeds + sea urchin + sea cucumber + abalone (bottom culture)
Japan	shrimp + *Ulva*
Norway	salmon + mussel + seaweed
USA (Maine) (Hawaii)	salmon + *Porphyra* shrimp + *Gracilaria*
Chile	seaweed biofilter – *Gracilaria* + turbot
Philippines (with Norway)	sea urchin/sea cucumber + *Eucheuma/Gracilaria*
France	sewage treatment system – *Ulva*
South Africa	finfish aquaculture effluent + *Gracilaria*
Southeast Asia	shrimp + seaweeds (primarily *Gracilaria*)
Australia	shrimp + oyster + *Gracilaria*

Phytoremediation

Phytoremediation is considered as an efficient approach with potential for removing aquatic contaminants. Much research has been conducted to identify plant species capable of accumulating undesirable toxic compounds such as heavy metals, and numerous plants are known to accumulate metals from their environment. Phytoremediation used in removing aquatic heavy metals is a newly developed environmental-protective technique. Studies concerning freshwater resources decontamination are extensive, and some freshwater plants have been found to have the capability of accumulating heavy metals, among which water hyacinth is the most noteworthy. Other freshwater plant species, such as *Hydroxotyle umbellate*, *Lemna minor* and *Chlorella vulgaris* are also used in studies of phytoremediation.

Few studies have been conducted on marine macroalgae. Brown marine algae, such as *Ascophyllum nodosum* and *Sargassum aquifolium*, can accumulate metals that occupy more than 30 percent of the biomass dry weight. Being unicellular marine algae, *Tetraselmis suecica* and *Chlorella* spp. NKG16014 are used in heavy metal bioremediation. Some experiments have shown that gametophytes of *Laminaria japonica* play an important role as a heavy metal decontaminator, especially to cadmium (Cd). Clean seawater is required in the breeding of algae and marine animals in aquaculture. The use of marine algae as efficient heavy metal decontaminators can assist in ensuring a suitable environment in hatcheries and also in sustaining clean environments in mariculture areas.

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ABSTRACT

Marine fish culture in China, Hong Kong, Special Administrative Region (China, Hong Kong SAR) involves the culture of fish in cages suspended from rafts in the sea. The activity is regulated by the Marine Finfish Culture Ordinance Cap. 353. All marine fish culture operations are required to be licensed and conducted in designated areas. Grouper is the major species cultured in China, Hong Kong SAR (over 50 percent). Other significant species include snappers, seabreams and pompano. Cultured marine finfish production in 2005 was 1 500 tonnes, with a farm gate value of US$9.7 million.

Fish disease has been a difficult problem encountered by fish farmers. Under the Fish Health Inspection Programme, fish farms are visited regularly to facilitate early detection of disease outbreaks and to advise fish farmers on good husbandry techniques and disease prevention measures.

After the 1998 red tide episode, a comprehensive red tide management programme was implemented. It comprises an interdepartmental red tide reporting network, a phytoplankton monitoring programme, a Geographic Information System (GIS), and various contingency plans to address different issues including mariculture, food safety and human health.

To investigate the possibility of reducing the impact of self-pollution from fish- farming activities, a trial study on the efficiency of artificial reefs (AR) as a biofilter in fish culture zones was conducted. The study aimed at quantifying the efficiency of AR in removing nutrients from fish farms and evaluating the changes in environmental and biological conditions after AR deployment. According to field studies and modelling, deployment of 16 pieces of 3x3x4 m specially designed AR can remove an estimated 2 352 kg, 624 kg and 103 kg per year of carbon, nitrogen and phosphate, respectively.

India

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MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKETS

Among the Asian countries, India ranks second in culture and third in capture fisheries production and is one of the leading nations in marine products export. The present marine fisheries scenario is characterized by declining yields from inshore waters and increasing conflicts among stakeholders, whereas the increasing demand for fish in domestic and export markets indicates good prospects for large-scale sea farming and coastal mariculture.

The contribution of fisheries to Indian gross domestic product (GDP) is about 1.2 percent (2002–2003), which forms about 5.2 percent of the agricultural GDP. The mariculture potential of India is vast, as there is great scope for developing farming of shrimps, pearl oysters, mussels, crabs, lobsters, seabass, groupers, mullets, milkfish, rabbitfish, sea cucumber, ornamental fishes, seaweeds, etc. Although about 1.2 million ha is suitable for land-based saline aquaculture in India, currently only 13 percent is utilized. Mariculture activities are presently confined to coastal brackishwater aquaculture, chiefly shrimp farming. Shrimp is the most demanded product from coastal aquaculture, and India is the fifth largest producer of cultured shrimp. Farmed shrimp contributes about 60 percent by volume and 82 percent by value of India's total shrimp export. The share of cultured shrimp export is 78 700 tonnes valued at Rs 33 000 million.[1] The area under shrimp farming is about 135 000 ha and average production is about 80 000 tonnes/year. In recent years, the demand for mussels, clams, edible oysters, crabs, lobsters, seaweeds and a few marine finfishes has been continuously increasing and many of these commodities bring premium prices in the international market. The other activities that can be categorized as artisanal mariculture include green mussel farming, lobster fattening, crab farming, edible oyster culture, clam farming and seaweed culture. The farming of green mussel yields about 4 500 tonnes, farmed oysters 800 tonnes, and farmed seaweeds about 1 000 tonnes, while quantities produced are not significant for crabs, lobsters, mullets and milkfish. A flourishing international trade in marine ornamental fishes is also in vogue that offers scope for their culture.

Shrimp farming is largely dependent on smallholdings of less than 2 ha, as these farms account for over 90 percent of the total area utilized for shrimp culture. Coastal aquaculture is concentrated mainly in the states of Andhra Pradesh, Tamil Nadu, Orissa and West Bengal. A long coastline of 8 129 km, along with an adjacent landward coastal agro-climatic zone and seaward inshore waters with a large number of calm

[1] US$1 = Rs 45 approx.

bays and lagoons offers good scope to develop mariculture in the country. Although the techno-economic feasibility of several mariculture technologies has already been demonstrated, lack of adequate infrastructure and lacunae in legislation block their implementation.

Local and international product demand, trade and market trends

Mariculture-related development in infrastructure, technology, processing, value addition and trade in India is almost entirely targeted at and anchored on the prospects for export and earning of foreign exchange. This is explicitly evident from the fact that 50 percent of the gross earnings generated from Indian marine fisheries are accounted for by crustaceans and cephalopods. Further, more than 90 percent of the aquaculture shrimp production is meant for the export markets. The overall average unit value realized for all fish in the domestic marketing system is about Rs 70 per kg as against Rs 148 per kg in export marketing (2003–2004). Export of marine products set an all-time record of US$1.48 billion in 2004–05. Exports increased by 11.97 percent in volume, 9.11 percent in rupee (Rs) value and 11.10 percent in US$ realization. The European Union emerged as the largest market for Indian marine products, accounting for 27 percent of the total exports, while the United States of America (USA) held the second position with a 23 percent share in exports. Frozen shrimp continued to be the main item in terms of value (64 percent of the total export value), and frozen fish continued to be the largest item in terms of volume (35 percent of the total export volume). India's share in the booming world trade of fish is less than 2 percent, which is very low considering the huge potential for exports. Within the ever-expanding internal market, fish and fishery products also recorded the highest increase among all food products. The dwindling catch rates in capture fisheries and rampant disguised unemployment in the coastal region focus governments and the private sector on the development of mariculture and coastal aquaculture as a source of remunerative alternate occupations.

Role of aquaculture vs. fisheries as supply

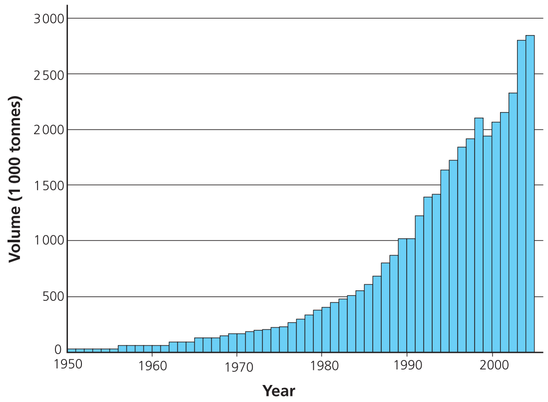
The fisheries production pattern in India is presented in Table 1.

TABLE 1
Fish production and average annual growth rate for India (Source: Tenth Plan Document (Fisheries) Government of India; figures from Central Marine Fisheries Research Institute (CMFRI), Kochi up to 1970–71; State government figures after 1970–71) [1]

Year	Fish production (1 000 tonnes)			Average annual growth rate (%)		
	Marine	Inland	Total	Marine	Inland	Total
1950–51	534	218	752	-	-	-
1960–61	880	280	1 160	5.12	2.53	4.43
1970–71	1 086	670	1 756	2.13	9.12	4.23
1980–81	1 555	887	2 442	3.65	2.85	3.35
1990–91	2 300	1 536	3 836	3.99	5.64	4.62
1991–92	2 447	1 710	4 157	6.39	11.33	8.37
1992–93	2 576	1 789	4 365	5.27	4.62	5.00
1993–94	2 649	1 995	4 644	2.83	11.51	6.39
1994–95	2 692	2 097	4 789	1.62	5.11	3.12
1995–96	2 707	2 242	4 949	0.56	6.91	3.34
1996–97	2 967	2 381	5 348	9.60	6.20	8.06
1997–98	2 950	2 438	5 388	-0.57	2.39	0.75
1999–2000[2]	2 834	2 823	5 657	5.12	10.02	7.51

[1] Growth rates prior to 1992–93 represent annual average compound growth rates.
[2] Provisional figure.

Figure 1
Aquaculture in India, 1950–2003
(Source: FAO, 2003)



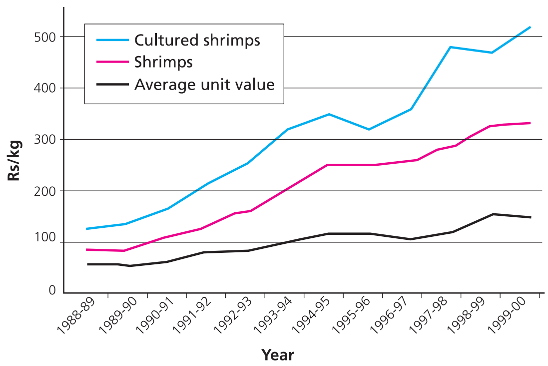
The total fish production during the four decades between 1950–51 and 1990–91 showed an annual average compound growth rate that varied between 3.35 and 4.62 percent (Figure 1). In the early 1990s, there was a boom in total fish production followed by a sluggish trend due to a pattern of decreasing marine production towards the end of the decade. It may be noted from the analysis that the trend for the marine fisheries sector was towards slack production in most of the years, whereas inland production grew throughout. It can be broadly stated that marine fish production has grown at a compound annual growth rate of 3.54 percent over the five decades since independence, while the growth of inland fish production has been dynamic over the same period, with a growth rate of 5.84 percent.

In 2003, aquaculture alone contributed one-third of the total fish production in India. Of the total aquaculture production of 2.3 million tonnes, production of carp was 1.87 million tonnes, giant river prawn was 30 000 tonnes and marine shrimp (*Penaeus monodon*) was 115 000 tonnes.

Aquaculture production from India in 2000 was 2 095 000 tonnes worth US$2 166 million. The shrimp exports from India during 2001–02 were 127 656 tonnes worth Rs 41 320 million. The cultured shrimp production during 2001–02 was 127 170 tonnes, of which 74 826 tonnes was exported, fetching Rs 36 450 million. Cultured shrimp contributed about 60 percent in terms of quantity and about 86 percent in terms of value to total shrimp exports during 2001–02.

In the 1970s and early 1980s, shrimp exports stagnated at around 50 000 tonnes per annum and the export earnings were below Rs 3 500 million. Twenty years ago, the price of white prawn was Rs 8/kg and that of tiger shrimp was Rs 13/kg. During the same period, brown varieties fetched only Rs 2–3/kg. Sathiadhas et al. (1989) reported that the unit price for white prawns during 1986–88 was Rs 40/kg. The price of tiger shrimp and brown varieties was only Rs 60/kg and Rs 10/kg, respectively. During the last few years, the prices of all aquaculture products have increased considerably. However, with the development of shrimp culture since the mid-1980s, the shrimp exports began to rise significantly, both in terms of quantity and value. The growth in terms of value has been more spectacular, because the cultured shrimp fetched more unit value in comparison to marine captured shrimp (Figure 2).

Figure 2
Contribution of farmed shrimps to marine exports



Total shrimp exports and the contribution of cultured shrimp to it are given in Tables 2 and 3. The share of farmed shrimp in total shrimp exports has been continuously increasing since the mid-1980s. In 1988–89, the share of cultured shrimp was only 33 percent by quantity; however, by the end of 2000 it had increased to 59 percent. Although the percentage of cultured shrimp by quantity is half of India's total shrimp exports, its contribution by value is much more. The value of Rs 2 293 million in 1988–99 increased to Rs 38 700 million in 2000–01, which was 86 percent of the total shrimp exports in that year. This value realization was mainly the result of the larger and more uniform size composition of cultured shrimp. There was a decline in the contribution of cultured shrimp in 1994–95 and in the subsequent two years that was due to disease outbreaks and the stoppage of culture activities in the Coastal Regulatory Zone (CRZ) area. During the years 1998–99 to 2000–01, however, the culture production increased and the contribution also showed a significant rise, registering an all time high of 58.8 percent in terms of volume and 86.4 percent in terms of value to the total shrimp exports. The quantity of shrimp exported increased to 128 000 tonnes in 2001–02 and to 135 000 tonnes in 2002–03. The value realized by cultured shrimp has also gone beyond 80 percent of the gross earnings of shrimp exports.

TABLE 2
Contribution of cultured shrimp (quantity) to total shrimp exports from India (Source: Ganapathy and Viswakumar, 2001; Pillai and Katiha, 2004)

Year	Total quantity of shrimp exports (tonnes)	Quantity of cultured shrimp exports (tonnes)	Contribution to shrimp exports (%)
1988–89	56 835	18 300	33.00
1989–90	57 819	19 500	33.72
1990–91	62 395	23 075	36.98
1991–92	76 107	26 000	34.16
1992–93	74 393	30 550	41.06
1993–94	86 541	40 300	47.14
1994–95	101 751	53 853	52.92
1995–96	95 724	47 922	50.96
1996–97	105 426	45 945	43.58
1997–98	110 318	43 712	42.90
1998–99	102 484	53 712	52.41
1999–00	110 275	54 000	48.96
2000–01	111 874	65 894	58.90
2001–02	127 709	102 940	58.80
2002–03	134 815	115 320	60.08

TABLE 3
Contribution of cultured shrimp (value) to the total shrimp export earnings from India (Source: Ganapathy and Viswakumar, 2001; Pillai and Katiha, 2004)

Year	Total value of shrimp exports (Rs Crores)[1]	Value of cultured shrimp exports (Rs Crores)	Contribution to export value (%)
1987–88	425.78	-	-
1988–89	470.33	229.30	48.78
1989–90	463.31	259.74	59.57
1990–91	663.32	376.40	56.77
1991–92	966.16	544.76	55.81
1992–93	1 180.26	766.25	64.93
1993–94	1 770.73	1 288.93	72.79
1994–95	2 510.27	1 866.23	74.35
1995–96	2 356.00	1 531.69	64.09
1996–97	2 701.78	1 642.56	60.80
1997–98	3 140.56	2 086.00	66.42
1998–99	3 344.97	2 511.00	75.07
1999–00	3 645.22	2 782.00	76.32
2000–01	4 481.51	3 870.00	86.35
2001–02	4 139.92	3 845.00	85.63
2002–03	4 608.31	3 793.86	82.33

[1] 1 Crore = 10 million Rs.

Coastal aquaculture is a significant contributor to marine fish production, which is comprised mainly of shrimp such as *Penaeus monodon* and *Litopenaeus indicus*. However, vast water bodies highly suitable for aquaculture and a varied biodiversity that has the potential to capture new markets with a wide range of seafood products have prompted consideration of other candidate species like oysters, mussels, crabs, lobsters, scampi, seabass, groupers, sea cucumber, ornamental fishes and seaweeds in the new aquaculture scenario in the country. Hatchery and rearing techniques have also been standardized for many of these organisms. Coastal aquaculture in India is mainly confined to shrimp culture. Considering the vast domestic market with huge demand for fish, there is enough scope for diversification to other cultivable species such as mud crabs, finfishes, oysters, mussels, sea cucumber, pearl oyster, etc. Although India does not have the advantage of extensive shallow seas with calm waters, there exist many potential mariculture sites that are still unutilized, offering tremendous scope for mariculture. Low-cost user-friendly bivalve mariculture practices provide seasonal vocation for rural folk. Polyculture of compatible species also offers a viable alternative to shrimp farming. Both require fewer inputs than shrimp culture and are economically viable. Hence the promotion of location-oriented, resource-specific mariculture is ideal for maintaining sustainable production without endangering the existing environmental equilibrium of natural resources.

The major molluscan product exports from India include frozen mussel meat, snail meat, freeze-dried clam meat, boiled clam/whelk meat, seashells and dried clam meat. South Africa became the largest market for frozen clam meat during 1999–2000, with an import of 32 tonnes worth Rs1 890 000 (MPEDA data). *Katelysia opima*, *Meretrix meretrix* and *Meretrix casta* were the major clam species exported from India. Among the molluscan products, freeze-dried clam fetches the highest unit value (Rs 430/kg) (Table 4). Two kilograms of cultured pearls were also exported during 1996, fetching a value of Rs 357 000/kg. The scope for the export of cultured pearls is enormous. Hence there is a bright future for sea farming of pearl oysters in India to produce export-quality pearls.

TABLE 4

Frozen mussel meat exported from India along with revenue realized from 1996 to 2003 (Source: MPEDA)

Year	Quantity (kg)	Value (Rs)	Unit value (Rs/kg)
1996	12 133	8 179 938	67
1997	24 773	1 739 989	70
1998	20 513	1 273 226	62
1999	35 989	1 807 231	50
2000	106 445	7 493 917	70
2001	482 097	29 007 630	60
2002	106 937	9 226 164	86
2003	74 982	4 975 491	66

A substantial quantity of crabs and crab products is also being exported from India. The details of live crab export from India are given in Table 5. The unit value realized for live crabs increased from Rs 119/kg in 1996 to Rs 195/kg in 2003, showing a steady increase in demand for live crabs in the international market.

TABLE 5
Live crab trade (Source: MPEDA)

Year	Quantity (kg)	Value (Rs)	Unit value (Rs/kg)
1996	2 028 430	240 692 690	119
1997	1 482 659	191 712 499	129
1998	1 777 198	306 427 388	172
1999	1 503 454	261 008 303	174
2000	1 579 704	260 923 450	165
2001	1 190 214	197 306 436	166
2002	1 958 748	400 060 486	204
2003	1 455 454	284 341 287	195

Exports of crabs and crab products from India were mostly confined to four types of products until recently. During 2000 the total number of crab products in India's export basket rose to 11, indicating that there is an increasing demand for diversified crab products. The different items in the export basket are crab shells, frozen cut swimming crab, frozen mud crab, frozen crab claws, frozen whole crab, frozen softshell crab, frozen stuffed crab, frozen pasteurized crab, frozen crab meat, frozen cut crab with claws and live crabs. Total crab exports were 1.1 percent of total marine exports in terms of quantity in 1996 and increased to 1.47 percent in 2000. In 2000, crab exports stood at 6 197 tonnes and the value realized was US$5.5 million, indicating their large potential for the export market.

The annual yield from crab fattening was significantly higher than that of crab culture. About five or six crops can be obtained annually through crab fattening as compared to only two crops from crab culture. Average yield from crab culture was 2 800 kg/ha/crop and that from fattening was 3 100 kg/ha/crop. Average body weight of the crabs obtained through culture was 800 g, whereas that of those from crab fattening was 850 g. The weight increase after 30–40 days of fattening was very little, ranging 50–100 g. Average food conversion ratio (FCR) calculated for 4–5 months culture was 4.9, which was higher than the FCRs of other local aquaculture species.

The international demand for lobster has continued to increase over the years, and targeted fishing has led to over-fishing in Indian coastal waters. Although the unit value realized for each product derived from lobster has increased, the overall value has declined, as more and more small-sized lobsters are caught from our open sea. It is highly advisable to promote the mariculture of lobsters wherever possible. Data for frozen lobster exports from India during 1999–2003 are shown in Table 6.

TABLE 6
Frozen lobster exports from India, 1999–2003

Year	Quantity (kg)	Value (Rs)	Unit value (Rs/kg)
1999	1 363 594	661 542 732	485
2000	1 555 166	802 049 638	516
2001	1 125 666	654 731 490	582
2002	1 008 394	575 601 161	571
2003	806 290	380 467 756	472

Similarly, demand for finfish also recorded a steady growth over the last few years, both in export and domestic markets. Mariculture of mullets, groupers, milkfish, etc. is quite possible in view of their increasing unit value realization (Table 7).

TABLE 7
Frozen finfish exports from India, 1996–2002

Year	Quantity (tonnes)	Value (Rs million)	Unit value (Rs/kg)
1996	10 093	3 722.6	37
1997	173 005	6 369.2	37
1998	188 029	7 267.3	39
1999	126 474	5 257.7	42
2000	188 822	7 697.2	41
2001	185 457	7 614.9	41
2002	217 195	9 064.5	42

The WorldFish Center and the National Centre for Agricultural Economics and Policy Research (NCAP) have estimated the supply demand projections under different scenarios. Accordingly, the annual production of inland fish in the year 2005 will be in the range of 3.6–3.7 million tonnes and will reach to 4.6–5.5 million tonnes in 2015, with an annual growth rate of 2.9–4.0 percent under different scenarios. The share of inland fish in total production, which was about 50 percent in the year 2000, will increase to 61 percent in 2015.

The production of marine fish is likely to be in the range of 2.9–3.0 million tonnes in 2005 and 3.2–3.6 million tonnes in 2015. Fish production is predicted to grow at an annual rate of 2.9–4.0 percent for inland fish and in the range of 1.2 to 1.8 percent a year for marine fish. The share of marine fish in the total fish production is expected to decline from 50 percent in 2000 to about 40 percent in 2015.

Varying estimates quantify the per capita fish consumption at around 8–10 kg per annum. Future demand for fish and fish products will grow substantially due to escalating population growth and increasing per capita fish consumption. The consumption of fish is projected to increase from 5.2 million tonnes in 1998 to 6.0 million tonnes in 2005 and to 7.7 million tonnes in 2015. Out of this, in-home consumption accounts for about 66 percent, while the rest will be consumed away from home or enter industrial processing.

Changing consumer preferences and buying patterns

The demand for fish is determined by factors such as increase in the number of consumers and increasing preference for seafood backed by growing purchasing power. Consumer preferences and patterns have shifted from cereals and other items to more nutritive yet affordable animal products like fish. According to National Sample Survey Organization (NSSO) figures, the per capita cereal consumption is declining, recording a decline of 0.52 percent per annum in rural areas and of 0.23 percent per annum in urban areas during the period 1970–71 to 1991–92. This shift in dietary pattern may be attributed to diversification in the food basket in favour of non-cereal food items like eggs, meat and fish. There has been considerable product diversification and market expansion of fishery products over the last three decades. There is increasing demand for "ready to cook" or "ready to serve" type seafood – hygienically prepared and attractively packed convenience foods to match the changing needs of urban populations. Seafood processing and marketing have become competitive all over the world, and exporters are switching over to value addition to increase profitability.

Aquaculture production and marketing are very closely inter-linked. The present level of trade through different marketing channels of different farming systems, the price spread at various stages of movement and the share of the producer in the consumer's rupee should be evaluated to formulate further strategies for the development of the aquaculture industry.

Aquaculture products, especially shrimp, undergo a lot of changes during peeling and processing. The head-on raw material is converted into either headless (HL) product by removing the head (35 percent) or into peeled and un-deveined (PUD) and peeled and deveined (PD) products by removing head, shell and the gut contents (50 percent). At various stages of the marketing system, a unit weight of shrimp undergoes considerable weight loss and corresponding price increase.

Export-quality prawns are graded based on their size, weight and quality. Domestic market products are graded into two or three groups based on their size. Marketing of value-added products of prawns and other aquaculture products such as live crab, edible oyster and pearl oyster are gaining importance. The flow of aquaculture products can be broadly divided into two categories depending on the ultimate destination of the product. High-unit-value products like prawns are reaching export markets, while low-unit-value products like finfishes and small crabs reach the domestic market.

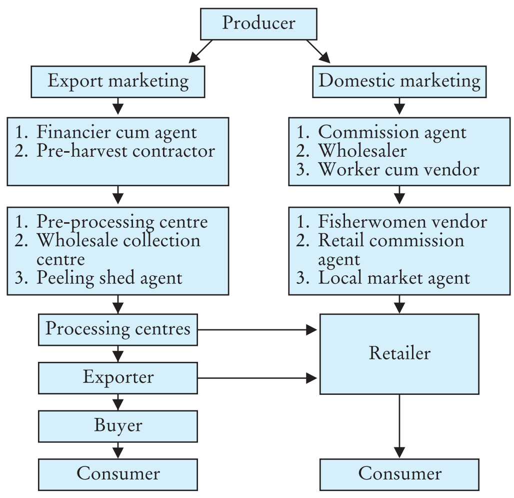
The Marine Products Export Development Authority of India (MPEDA) has listed about 65 value-added products suitable both for export and domestic markets. Product diversification helps promote price discrimination and enables realization of maximum foreign exchange earnings. It also helps to enhance the employment opportunities of coastal and rural women. The emergence of value-added products is accelerated by the current demand pattern of the major seafood markets in exporting countries. People have become more selective in their food choice and they are ready to spend more for food. All over the world, the current tendency is to purchase convenience foods such as assembled meals rather than preparing them from basic ingredients. The most advisable and viable alternative to maximize our shrimp exports is through value-added ready-to-eat products. An additional export of 100 000 tonnes of value-added products in our marine products could easily generate about Rs 15 000 million in foreign exchange earnings and provide regular employment to about 35 000 fisherfolk.

Market chain organization

Trade flows and market chains

Fish passes through a number of hands before it reaches the ultimate consumers. Both domestic and export marketing have several entirely different flows of products through different marketing channels. The flow of aquaculture products from producer to consumer on export and domestic market is shown in Figure 3. The export marketing system has five main marketing channels where the products pass from one to four intermediaries. The domestic marketing system can also be classified into five channels. There is considerable variation in the unit price of products moving through export and domestic marketing channels, the products moving through export marketing channels having five times higher unit price than those moving through the domestic channels. There is an interrelationship between the different intermediaries involved in the marketing flow.

Figure 3
Marketing channels in domestic and export marketing in India



Price spread is bound to increase within the proliferation of marketing agents performing the services of procurement, assembling, storage, transportation, peeling, processing, packaging, holding, clearing formalities and exporting. It will also be influenced by the degree of marketing control exercised by the government policies. An increase in price spread will soon result in rises in consumer price.

The best export marketing channel involves a maximum of two intermediaries (such as exporters and buyers) between the producer and the consumer. This is the best marketing channel for the producer available in India under the present system of aquaculture product marketing. This system of marketing is available mainly for the commercial semi-intensive farms of Nellore, Guntur and Tuticorin. Here the exporter owns a shrimp farm or gives a contract to other entrepreneurs through a buyback agreement. Hence the exporter gets a regular supply of the product according to the demand of the buyer. The harvested shrimp are usually also able to reach the processing unit in a better condition, and producers get a maximum price for all size grades.

A marketing channel involving only the essential intermediaries such as exporter cum processor and foreign buyer is the most suitable marketing system. A system of well organized cooperative marketing, along with financial assistance from such agencies as MPEDA, the Brackishwater Fish Farmers Development Agency (BFFDA), the National Bank for Agriculture and Rural Development (NABARD) and state banks can enhance the producer's share and reduce the role of financier-cum-agents and money lenders. Vulnerability issues in marketing are listed in Box 1.

BOX 1

Vulnerability issues in marketing

These include:

- Uncertainty in supply and demand
- Price fluctuations
- HACCP and quality issues
- Changing international trade regulations
- The perishable nature of the products
- Too many varieties and too many demand patterns
- Assembling the products from too many distant and remote centers
- Too many intermediaries in the marketing channel
- Inadequate storage facilities
- Lack of refrigerated transporting system
- Lack of vertical and horizontal integration of markets

The successful experiment of mussel farming in Padanna demonstrates that parallel development of a domestic marketing system is essential for the introduction and growth of any new product. Domestic consumption of mussel is very noticeable in northern Kerala. Farmers have to harvest the fully grown mussels in May and sell them before the onset of monsoon to avoid mortality due to low salinity. At present only a few companies are purchasing mussels from farmers, and thus the farmers' bargaining power is very restricted. The growth of women's Self Help Groups (SHGs) and vertical integration for export marketing has helped the spread of mussel farming in this region.

Market chain

In the case of marine fish domestic marketing, fish travels long distances from coastal areas to interior parts of the country. The usual marine fish marketing channels prevailing in India are given below:

1) Fisher > Auctioneer > Agents of freezing plants > Exporters
2) Fisher > Auctioneer > Processor (dry fish) > Wholesaler > Retailer > Consumer
3) Fisher > Auctioneer > Wholesaler (primary market) > Wholesaler (retail market) > Retailer > Consumer
4) Fisher > Auctioneer >Commission Agent > Wholesaler > Retailer > Consumer
5) Fisher > Auctioneer > Retailer > Consumer
6) Fisher >Auctioneer > Consumer

The major portion of domestic fish marketing takes place through the 3rd to 6th channels. The auctioneers of the primary market and commission agents of the secondary market are also involved in the process, although without taking actual possession of the fish. Fish marketing in India can be divided into two categories – domestic fish marketing and export marketing. In India, fish marketing has not developed fully on modern lines. There has been a gradual transformation from traditional to modern methods of marketing with the advent of improved transportation, processing and storage facilities. The involvement of a number of middlemen in the marketing chain adversely affects the interest of both fisherfolk and consumers.

LIVELIHOOD OPPORTUNITIES AND MARICULTURE

Poverty status and livelihood vulnerability of coastal communities

Emerging economic growth, shifting dietary patterns in favour of fish consumption and continuously rising prices have resulted in increased pressures on wild fish stocks and associated inter-sectoral conflicts in coastal areas. Among the people living around coastal and inland waters, fisherfolk are one of the most underprivileged groups, being affected by such problems as inadequate employment; food insecurity; closed seasons; dwindling catch rates; problems in production, post-harvest and marketing; and indebtedness.

Increasing poverty among coastal fisherfolk

In India, poverty is of great concern. Although data vary, the results of the 55th round of the National Sample Survey show that the percentage of people below the poverty line in India decreased from 36 percent in 1993–94 to 26 percent in 1999–2000. The vast majority of India's poor, estimated to be anywhere between 320–400 million, live in rural areas. A study by the International Food Policy Research Institute (IFPRI) notes that while overall economic growth has been impressive since the start of reforms in the early 1990s, a positive impact on rural poverty has not been observed. The failure to reduce rural poverty is attributed to declining public investment in agriculture, which provides a livelihood to 70 percent of Indians. Trade liberalization in recent years has also led to extreme price volatility in many agricultural products that has hurt poor farmers. Agricultural growth has declined in recent years, a trend that is expected to continue. In 1994–95, agriculture grew at a rate of 5.0 percent, followed by a negative growth of 0.9 percent the subsequent year, then a positive growth of 9.6 percent in 1996–97 and then negative growth of 1.9 percent in 1997–98.

The incidence and persistence of poverty in the fisheries sector can be attributed mainly to the open access nature of marine fisheries, the slow pace of aquaculture/mariculture development and unconstrained labour mobility (FAO, 2005). Labour mobility to fisheries is accentuated by social factors such as the caste system prevailing in India. There is considerable growth of population within the fishing community, and newer technologies are being adopted that pave the way to biological and economic overfishing and reduced per capita production, which emphasizes the need for efficient fisheries management directed primarily towards sustainable development and equitable distribution of benefits. The economics of different craft/gear combinations and per capita earnings of fishing labour clearly indicate that not less than 60 percent of people in the coastal rural sector live below the poverty line. It is clear that coastal rural people have not received much of the benefit of economic development since India became independent.

Employment within the primary capture fisheries and aquaculture production sectors in 1998 was estimated to be about 36 million people, comprising about 15 million full-time, 13 million part-time and 8 million occasional workers. Employment in aquaculture (inland and marine) has been increasing and is now estimated to account for about 25 percent of the total (Government of India, 2001).

In spite of the regional dimensions of economic growth in India, sectoral disparity, inequality in income and poverty incidence in the fisheries sector have been increasing over the years. This information is important, owing to the fact that inequality cumulated over a period of time has a substantial impact on the standard of living of people (Barro and Sala-i-Martin, 1995). Income distribution is one of the most critical issues of development economics and is closely related to emphasis on poverty reduction as the most important goal for development (Kakwani, Khandkar and Son, 2004).

In spite of India's planned economic development that is aimed at reducing spatial and sectoral disparities in income, such disparities have been increasing over time. Large disparities and negative growth rates undermine the integration of the economies and social stability, hampering long-term economic growth, the fisheries and aquaculture sectors being no exception. The physical productivity of worker per unit of capital invested has declined steeply, which is a phenomenon characteristic of open-access resources subject to increased commercialization (Kurien and Antonyto, 2001). The recent measure of liberalization of transition economies, India being on list of the late adopters, aggravated the problem of disparities, owing to the introduction of measures that curtail the supportive measures offered to the fisheries sector. The rise in inequality in the fisheries sector results from the following factors:

- shift to capital-intensive technologies and labour-saving devices;
- technological innovations leading to marginalization;
- drop in the rate of labour absorption in the capture/mariculture sectors;
- disguised unemployment;
- failure of coastal aquaculture/mariculture to emerge as an alternative vocation;
- lack of integration of mariculture with inshore capture fisheries; and
- lack of legislation for open-sea mariculture.

Current experiences and better practice

The success story of IVLP by CMFRI

The Institution Village Linkage Programme (IVLP) for Technology Assessment and Refinement (TAR) is one of the most important segments of the National Agricultural Technology Project (NATP) for testing, improving and refining technologies prevailing at or generated for diverse production systems. The Central Marine Fisheries Research Institute (CMFRI) has implemented the programme in the coastal village of Elamkunnapuzha in Ernakulam District of Kerala from August 2000 through April 2005. Altogether 31 techno-interventions were assessed and refined in farmer's fields (13 fisheries, 5 livestock and 13 agriculture). A total of 687 farm families participated in these interventions, and the total population covered under this programme was 3 435. The programme has been successful in building linkages among farmers, fisherfolk, research institutions, agricultural universities and the local extension system. It has imparted diverse packages of technical knowledge through 15 field-level training programmes in which 576 farmers, of which 318 were female, participated. The overall impact of this intervention is highly promising and is termed the "Elamkunnapuzha Model of Development".

The most important impact of IVLP is the adoption of diversified aquaculture practices by the farmers. The comparative yield levels of different types of fish culture under recommended practices have shown marked improvements. Hitherto the farmers mostly concentrated on shrimp-oriented aquaculture. The high price of shrimp coupled with its export potential attracted farmers to this type of aquaculture irrespective of its suitability and cost of production. Shrimp culture was not ideal for most of the farms and was also less profitable than other culture practices such as fish and crab. A least-cost combination of production factors coupled with the high suitability of ponds for monoculture of crabs, mullet (*Mugil cephalus*) and milkfish (*Chanos chanos*) and the polyculture of different finfishes has shown profitability ranging from Rs 200 000/ha for monoculture of milkfish to Rs 700 000/ha for monoculture of juvenile crabs. The only constraint limiting the expansion of crab culture is the unavailability of hatchery-produced seed.

Farmers have shown much enthusiasm in continuing their efforts in commercializing the ventures. As far as fisheries-based interventions are concerned, around 30 percent of the farmers are using leased ponds. The lease rate of ponds has increased from Rs 8 500/ha during 2000–01 to Rs10 000/ha in 2003–04, an increase caused by diversified utilization and a consequent increase in demand for ponds. The seasonal employment pattern of fish/crab seed collectors also increased from about 80 to 120 labour days per annum. In the project village alone, an area of 22.3 ha that was previously unutilized has been brought under different fish-culture practices.

Livestock interventions have proved to be the most ideal supplementary avocation suitable for the coastal agro-ecosystem. The benefit-cost ratios of various animal husbandry practices clearly indicate the need to adopt scientific management practices. Such practices provide maximum opportunity for optimal utilization of homestead backyards and employment, mainly to women. The annual household income can be enhanced by Rs 2 150 by growing ten Gramalakshmi birds and by Rs 10 000 by growing five broiler rabbits of the grey giant variety. The cultivation of paragrass in the unutilized marshy lands has shown a potential yield of 10 tonnes/ha, indicating good prospects for the fodder-deficient island ecosystem.

In agriculture-based interventions, cultivation of improved varieties of vegetables yielded better returns as mono-crops and inter-crops along the embankment of fish ponds and also along homesteads. Although the yield from snake gourd (*kaumudi*) cultivation was better than that for all other vegetables, the net earnings (Rs 128 325/ha) are higher for bitter gourds (*preethi*). The impact of nutrient management in coconut plantations has shown an average increase of 30 nuts per tree per annum. The practice of nutrient management for all coconut trees in the entire village may have far-reaching impacts on the rural economy. Since there are about 100 000 coconut trees in the study area alone, adopting this single management practice could fetch additional revenue of about Rs 10 million in Elamkunnapuzha Village, even if we assume an additional 20 nuts per tree per year with an average price of Rs 5 per nut.

The IVLP model has ensured the active participation of stakeholders throughout the process of assessment and refinement of technology. Participatory Rural Appraisal and Livelihood Analysis has identified the location-specific problems, potential solutions and the extent of blending of the prevalent indigenous knowledge with scientific practices to optimize both yield and earnings. Economic feasibility and high profitability in on-farm and verification trials are visible, and farmers have largely adopted the improved farming practices. Integration of aquaculture with agriculture and animal husbandry has shown potential for generating additional employment opportunities and enhancing disposable household income.

Comparative economics of mariculture practices

A comparative picture of the various economic indicators of different aquaculture practices is given in Table 8. Cost of production was the highest for the crab culture system followed by the extensive tiger shrimp culture system. When profit per kg was compared across the different culture systems, the crab fattening system topped the list, followed by the extensive tiger shrimp culture system and the extensive Indian white shrimp culture system. Net profit and net operating profit were higher for the crab fattening system. Although profit realized per kilogram was highest for the crab fattening system, the inconsistent supply of crab seed prevents its large-scale adoption. Although profit realized per kg was higher for the extensive tiger shrimp culture system, the high production costs indicated the possible risk involved in the event of crop failure. Net operating profit of disease-affected tiger shrimp extensive culture systems was negative, whereas all other shrimp culture systems affected by disease could manage a positive net operating profit. The extensive Indian white shrimp culture system had moderate profit per kg and comparatively less production cost than the extensive tiger shrimp culture system.

TABLE 8
A comparison of economic indicators for different aquaculture practices

Key economic indicators	ET[1]	EW	CC	CF	MC	EO	MF
Net profit/ha (Rs)	92 986	123 407	43 982	538 237	37 544	4 401	12 989
Net operating profit/ha (Rs)	147 877	161 812	64 319	587 557	47 146	6 018	14 928
Cost of production/kg (Rs)	197	47	210	174	42	2.74	3.58
Profit/kg (Rs)	92	63	55	99	22	1.25	1.92
Input-output ratio	1.46	2.33	1.26	1.57	1.51	1.46	1.54
Break-even production (kg)	693	846	640	3 459	1 160	2 393	4 411
Break-even production as % of total production	68	43	79	64	66	69	65

[1] ET – extensive tiger shrimp culture system; EW – extensive Indian white shrimp culture system; CC – crab culture system; CF – crab fattening system; MC– milkfish culture system; EO – edible oyster culture system; MF – mussel farming system.

The crab culture system was the first to achieve break-even production, followed by the extensive tiger shrimp culture system and the extensive Indian white shrimp culture system. When the percentage of break-even production to the total production was compared among the different culture systems, the extensive Indian white shrimp culture system came first, followed by the crab fattening system. The economic indicators clearly show that mussel culture is more profitable than edible oyster farming. Although production cost per kg and break-even production were low for the edible oyster farming system, all other indicators favoured mussel farming.

Role of mariculture in poverty reduction as an alternative to fisheries

In the context of heightening demand for fisheries products, the importance of aquaculture has increased. Fresh and brackishwater fish culture are the main types of aquaculture activity in India. With the exception of shrimp farming, mariculture, despite its vast potential on both the landward and seaward sides of the coastal line has not developed. Technological developments like pearl oyster culture, edible oyster culture, mussel culture, lobster farming, crab culture, seaweed culture, sea cucumber culture and finfish culture have been developed by research institutes like CMFRI. Adoption of these techniques on a scientific basis can add to farmers' incomes and thus raise the standard of living.

One of the most adaptable alternative systems that can be offered to the coastal community is that of mariculture. The immediate need is to organize proper development, extension and training programmes for mariculture in the coastal communities. Also this effort should be supported by effective institutional finance linkages and forward and backward marketing linkages, so as to ensure effective and proper implementation of the programme.

Depending on the geographical and ecological diversities of the country, there are vast differences in the availability and suitability of areas that can be developed for mariculture and also in the candidate species available for cultivation. Shrimps and finfish like grey mullet, milkfish, pearl spot, seabass, groupers, red snapper, breams and pompanos are suitable for farming all along the Indian coast, especially along the southwest and southeast coasts. In addition, sea cucumber could be cultured along the coasts of Tamil Nadu and Lakshadweep; pearl oyster along the coasts of Tamil Nadu (Gulf of Mannar and Pak Bay), Kerala, Gujarat, Lakshadweep and the Andaman Islands; edible oyster in Andhra Pradesh, Tamil Nadu, Kerala, Karnataka and Gujarat; mussels in Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa and southern Maharashtra; windowpane oyster and red clam in Andhra Pradesh; clams in Kerala, Karnataka, Goa and Maharashtra; and seaweeds in the Gulf of Mannar, Gulf of Kutch, Kerala backwaters, Chilika Lake, Pulikat Lake and the lagoons and lakes in Lakshadweep and the Andaman and Nicobar Islands (Devaraj *et. al*., 1999).

The natural living resources of the Indian seas are rich, diverse and are distributed in a variety of ecosystems ranging from estuaries, to saline lagoons, low-lying saline inundated marshes, and the intertidal and subtidal belt to beyond the shallow coastal shelf waters and have immense value and use for humanity. Slowly but steadily aquatic resources have been depleted and habitats damaged by activities such as dumping of pollutants, land reclamation and destruction of mangroves. Many of these problems have taken place in easily accessible coastal waters that are fragile, sensitive ecosystems and have badly hit the more vulnerable and desirable species, as well as a wide spectrum of low-value, high-volume bottom biota forming part of the marine food chain.

Examples of introduction of mariculture into coastal communities

Mussel farming in Cheruvathur and Padanna, Kasargod District, Kerala: a success story

Kasargod, the extreme northern district of Kerala, is notable for mussel farming, as it has been successfully accomplished by women's Self Help Groups (SHGs) for the past few years. These groups were given financial assistance by the Swarnajayanthi Gramaswa Rosgar Yojana (SGSY) scheme by the state government, which takes care of economic empowerment of weaker sections of society. Subsidies, bank loans and other support are provided for poverty alleviation through organized SHGs. This programme looks into training, credit, marketing, technical knowledge and the basic facilities necessary to uplift the poor. This study was undertaken in two major *panchayaths*[2], namely Cheruvathur and Padanna in Kasargod District. Six SHGs of women (three each from both *panchayaths*) were selected for the study.

The major expenditure required for mussel farming is for materials such as bamboo, nylon rope, cloth, seed, etc. and labour costs essential to cover construction, seeding, harvesting, etc. The women's groups constituted under the Development of Women and Children in Rural Area (DWCRA) scheme started mussel farming as early as 1996–97 and were assisted by a loan amount worth Rs 8 800 per member with a subsidy amount worth Rs 4 400. The duration of the loan was five years and the rate of interest was 12.5 percent per annum. In addition, a revolving fund of Rs 5 000 was also provided without interest. When the SHGs are economically empowered with the provision of loans, the returns from mussel farming help them to slowly repay the loan.

The loan was granted through Farmers' Service Cooperative Banks and North Malabar Gramin Banks in Cheruvathur and Padanna *panchayaths* of Kasargod District. The majority of the SHGs showed considerable progress in repayment of the loans, which was interpreted as an indication of the profitability of mussel farming.

The net operating profit shown by all six SHGs confirmed the profitability of mussel farming during the initial trial. Since in subsequent years, material costs such as those of bamboo, rope and cloth and the cost of labour for construction, etc. are negligible, a reasonable profit as a major consequence of adoption of mussel farming is assured.

[2] The *Panchayat* is the tiniest elected empowered body of people's representatives in the local administrative set up.

The benefit-cost ratio for all six SHGs was above 1, indicative of considerable economic viability and potential in mussel farming.

The loan sanctioning, utilization, accounts maintenance and timely repayment, etc. are all perfectly accomplished with proper maintenance of the documented records by the group members. This ascertains the fulfilment of norms and standards of the SHG, leading to economic empowerment of the members.

An unsuccessful attempt in mariculture: case study of mussel farming in Karwar and Bhatkal, Karnataka State

SHGs of fisherfolk were mobilized in the Karwar and Bhatkal areas of the Karnataka coastal belts. Three SHGs of 15 members each were mobilized in Majali (open sea), Dhandebag, and three SHGs of 15 members each were mobilized in Sunkeri, Kali Estuary in the Karwar coastal belts, Uttar Kannada District, Karnataka State. Initially, two training and demonstration programmes in these two sites in Karwar were undertaken, one for raft culture in open sea in Majali and one for rack culture in Sunkeri. The training was imparted to the 45 members of the two SHGs, each possessing 15 members (a total of 90 participants). Similarly in Mundalli River of Bhatkal Estuary in Karnataka, four SHGs of 15 members each (total of 60 participants) comprised exclusively of women fisherfolk were mobilized under the nongovernmental organization (NGO) "Snehakunja" and trained in mussel farming.

The major expenditures required for mussel farming are for materials such as bamboo, nylon rope, cloth, seed, etc. and labour costs for construction, seeding, harvesting, etc. The SHGs of Majali and Sunkeri were mobilized by the project team of CMFRI, and the SHGs of Bhatkal were mobilized by the NGO Snehakunja. The first two trials and demonstrations were under the funding of CMFRI, while for the last trial only technical help during the training and demonstration were offered by CMFRI. The yield particulars for all SHGs were noted and considered to be quite good.

Mussel farming faces a number of impediments involving such variables as water salinity, seed availability, location/site selection, climatic vagaries, identification of proper beneficiaries and proper monitoring opportunities. The major problems and constraints faced by the fisherfolk in mussel cultivation are as follows:

- unpredictable seed availability;
- mortality of seed during transportation;
- reduced growth during certain years;
- lack of depuration facilities;
- lack of storage, cold room and cold chain;
- marketing of mussels; and
- social dynamics at the village level based on caste and politics.

The open-sea mussel culture in this particular case met with the impediment of sabotage of the seeded mussel by some miscreants. This was rectified by reseeding, but the yield was not comparable to that produced during the trials undertaken in estuaries. All the SHG members are of unanimous opinion that the government should come forward with suitable legislation for the allotment of water areas for open-sea mussel culture and improved marketing facilities. Provision of loans with reduced interest rates and freezer facilities for storage of harvested mussels could bring about a breakthrough in this sector in the near future.

Markets and coastal community development linkages

Forward and backward linkages are essential for the sustenance of any development initiative. Market-oriented production rather than production-oriented marketing should be promoted to ensure marketing efficiency and to overcome marketing problems. A need-based building of linkages would help in sustaining mariculture initiatives. Linkages that need to be developed include links among consumers, middlemen, agricultural/fisheries offices, NABARD, banks and other financial institutions, *panchayat* functionaries, NGOs, marketing outlets, local organizations, researchers and input suppliers.

Another linkage that should be developed is one that recognizes the consumer's changing needs and wants. Although highly relevant within the modern marketing context of branded consumer products, this idea can also be applied to fisheries marketing. Consumers can be educated about new fisheries products and encouraged to use them through information dissemination via the media. By the time the demand for these items is generated, production can also be initiated by mariculture activities. Adoption of this strategy can promote market-oriented production.

Financial linkages are essential in any development initiative. An activity that is not supported by financial assistance in the form of subsidies, credits or grants is not sustainable. Hence adequate backward linkages from the financial institutions/ government agencies have to be provided to ensure successful implementation and continuation of the programme. Because mariculture is not yet commercially exploited on a large scale, adequate support and extension are required for its adoption.

EXISTING AND POTENTIAL MECHANISMS OF TECHNOLOGY TRANSFER

There are no mechanisms exclusively targeted at mariculture extension. The departments of fisheries of each state government have extension officers who support the extension agenda of their state. The Brackishwater Fisheries Development Agencies in maritime states also have some responsibilities and mechanisms for guiding farmers and entrepreneurs. MPEDA has officers specially trained for the extension of shrimp farming and some other mariculture techniques. There are training programmes at the state and farmer level that are conducted by the state fisheries departments and MPEDA. State agricultural universities in the maritime states through their colleges of fisheries also have extension training and disseminate information to farmers.

Training centres of excellence

There are no training centres in India exclusively devoted to mariculture except for a training hatchery established in CMFRI at Kochi. CMFRI is the country's nodal agency that conducts post-graduate level courses in mariculture. It has hatcheries in Mandapam, Vizakhapatnam, Tuticorin, Calicut and Kochi that are used as training hatcheries. A Centre of Excellence in Mariculture is being developed at its regional centre in Mandapam Camp where there is an extensive farm area to be developed into a large marine farm. A modern hatchery is under construction at Mandapam. There is need for technical support and for organizing regular training programmes in mariculture, as being done elsewhere in the region, such as at the Southeast Asian Fisheries Development Center (SEAFDEC). CMFRI is also the Network of Aquaculture Centres in Asia-Pacific (NACA) National Seafarming Centre, although there is no programme ongoing at present. CMFRI is also the Centre of Advanced Studies in Mariculture of the Cochin University of Science and Technology.

There is great potential for developing a regular training programme at CMFRI and updating it into a Centre of Excellence. CMFRI has a Division on Mariculture located at Mandapam, where there are more than 14 scientists and over 100 technical and support staff, a guest house, running seawater facilities, laboratories, etc. MPEDA has a hatchery at Vallarpadom for shrimp that was used for imparting training until a few years back, but it is no longer functional. Some training is provided by NGOs and volunteer agencies (VAs), with the help of scientific organizations, but their impacts are low.

Existing and proposed mechanisms of technology transfer

The transfer of technology (TOT) depends upon three systems, i.e. the Knowledge Generating System (KGS), the Knowledge Disseminating System (KDS) and Knowledge Consuming System (KCS). The members of the KGS are research institutes, while the members of KDS consist of extension personnel and other TOT agencies. Besides this the KDS also includes the Input Supply Agencies (ISA) such as lead banks, fertilizer corporations and seed suppliers. The main function of KDS is to transfer the technology to KCS and collect feedback and pass it on to KGS. The KCS consists of farmers and other actual users of technology. The most effective TOT is possible when all three systems (i.e. KGS, KDS and KCS) are working in close cooperation. Thus there should be effective interaction and good relationships among all three systems.

The Indian Council of Agricultural Research (ICAR), though basically a KGS, has also taken up the task of technology transfer by launching various schemes in collaboration with state governments (KDS), agricultural universities and voluntary agencies. The various TOT programmes launched by ICAR include the All India Coordinated Research Projects, National Demonstration Programme, Operational Research Projects and the Krishi Vigyan Kendra Trainers' Training Centres and Lab-to-Land Programme. ICAR's scientists are actively engaged in these TOT programmes. This approach will develop the desired linkage between the KGS (ICAR and agricultural university), KDS (state government, voluntary and other extension agencies) and the KCS (the farmers and other users of the technology). This is a step in the right direction and will narrow the gap between the research and the extension systems.

Systems of extension in India

In the Indian context, there are four major organizational streams to TOT work for fisheries and rural development. These are:

- the first line extension system, comprising mainly the ICAR institutes and the state agricultural universities (SAUs);
- the extension system of the Ministry of Agriculture/Fisheries and the State Department of Fisheries;
- the extension system of the Ministry of Rural Development and the State Development Departments; and
- the development work done by the NGOs, business houses, etc.

Schemes for transfer of composite fish culture technology

In India, both the government and NGOs are presently engaged in dissemination of the technology of composite fish culture through various TOT schemes. Some of the important schemes include:

- All India Coordinated Research Project on Composite Fish Culture;
- National Demonstration;
- ICAR/State Government/Agricultural University Demonstration;
- Voluntary Organization Demonstration;
- Operational Research Project;
- Central Inland Capture Fisheries Research Institute (CIFRI)/IDRC Rural Aquaculture Project and CMFRI Mariculture projects;
- Fish Farmers' Development Agencies;
- World Bank Project;
- Krishi Vigyan Kendra;
- Trainers' Training Centre;
- Lab-to-Land Programme; and
- Agricultural Technology Information Centre (ATIC) of ICAR institutions and SAUs.

The approach is an example of a widespread TOT programme to promote one technology, the lessons from which might be adapted for other aquaculture technologies.

Present training activities and likely future requirements

Present training activities are limited to MFSc and PhD courses in mariculture at CMFRI, Kochi. This is far too low for a large country such as India. There is a need to upgrade the technical manpower, training capacities and infrastructure with funding support for regular training in mariculture for farmers and entrepreneurs at its Mandapam, Visakhapatnam and Calicut centres. India could develop as a major player in mariculture by diversifying into farming of finfish, molluscs, sea cucumbers, crabs, lobsters, seaweeds, etc. Great potential exists and there is urgent need to develop at least one centre of excellence in mariculture with technical and operational support from FAO/NACA at CMFRI, as it already has infrastructure, farm, hatchery and some scientists working on mariculture research. At least 100 persons could be trained every year in various mariculture technologies at this centre. Also, the MPEDA's Vallarpadam hatchery could be converted into a training centre via collaboration with CMFRI. The hatchery at the Central Institute for Brackishwater Aquaculture (CIBA), Chennai could also be used for shrimp hatchery training. CMFRI is upgrading its hatcheries at other centres and establishing a national Fish Seed Facility in Kochi for supplying fish seed to farmers. CMFRI has also commenced an Open Sea Cage Demonstration Farm at four sites, two on the east coast and two on the west coast. All these efforts will help to develop mariculture in India over the next five years.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Status of farming of selected species

Details of the mariculture potentials of the country are presented in Tables 9 and 10.

TABLE 9

Mariculture potential in India (Source: Devaraj *et al.*, 1999)

Area	TA[1] (million ha)	PCA (million ha)	CCA (million ha)	CAP (tonnes)
Coastal land-based	2.5	1.2	0.14	85 000 (mainly shrimp)
Hinterland saline soil aquifer-based	8.5	-	-	200 (milkfish, mullet, pearl oyster, scampi)
Sea Farming				
Open sea (EEZ)	202	1.8 (inshore 0–50 m depth)	-	1 500 (mussel)
Bays, coves & gulf	-	10 700	-	-
Estuaries & backwaters	-	2 050	5	800 (oysters)
Stock Enhancement Programme				
Sea ranching	18 (0–50 m depth)	18	Nominal	Nominal (shrimp, pearl oyster, clams, sea cucumber)
Artificial reef habitat	-	-	50 reefs	10
Bottom artificial reefs (FAD)	-	-	150 FAD	-

[1] TA = total area, PCA = potential cultivable area, CCA = current cultivated area, CAP = current annual production.

TABLE 10
Marine organisms of aquaculture importance in India

Species	Hatchery techniques[1]	Rearing technique
Fishes		
Mugil cephalus, Liza parsia, L. macrolepis,		
Valamugil seheli, Chanos chanos, Etroplus suratensis,		
Epinephelus tauvina, Lethrinus spp.	X	X
Sillago sihama, Anguilla bicolor & *Siganus* spp.		
Anemone fish, *Chromis* sp. & *Lates calcarifer*	XX	XX
Crustaceans		
Penaeus monodon, Litopenaeus indicus & *P. semisulcatus*	XXX	XXX
Scylla serrata	X	XXX
Portunus pelagicus	XX	XX
Panulirus homarus, P. ornatus		
P. polyphagus & *Thenus orientalis*	X	X
Molluscs		
Perna viridis, P. indica, Pinctada fucata		
Crassostrea madrasensis, Anadara granosa		
Meretrix meretrix, M. casta &		
Paphia malabarica	XXX	XXX
Trochus radiatus, Xancus pyrum,		
Sepia pharaonis, Loligo duvaucelli	X	X
Seaweeds		
Gracilaria edulis, Gelidiella acerosa, Porphyra sp.		
Sargassum spp., *Ulva* spp. & *Euchema* sp.	XX	XX
Sea cucumber		
Holothuria scabra	XX	XX

[1] X = techniques under development; XX = techniques developed; XXX = techniques developed and commercialized.

Existing major mariculture species and farming technologies

Lobster farming and fattening

Increasing demand for live lobsters and crabs in the export market led the farmers and entrepreneurs to collect juvenile lobsters and crabs from the wild and grow them to marketable size in ponds and tanks by feeding trash fish and other discards. In many maritime states, juvenile lobsters (*Panulirus homarus*, *P. ornatus*, *P. polyphagus* and *Thenus orientalis*) are grown in captivity, eyestalk-ablated lobsters attaining 180–200 g within 5 to 6 months. This type of lobster fattening, when conducted at a stocking density of 10–15 juveniles per m^2, yielded appreciable growth rates with a profit margin of Rs 50 000 from a pond of 70 m^2. Recently a major breakthrough in breeding and hatchery production of two species of scyllarid lobster, *Thenus orientalis* and *Scyllarus rugosus*, was achieved by CMFRI. Successful hatchery production of seed of *T. orientalis* was accomplished for the first time in India. Completion of the larval cycles of *T. orientalis* and *S. rugosus* was achieved in 26 days and 32 days, respectively.

Crab farming/fattening

Live mud crabs (*Scylla serrata*, *S. tranquebarica)* are a much sought-after export commodity; thus mud crab fattening was considered a good opportunity (Table 11). Seed stock consist of freshly moulted crabs (“water crabs”) of 550 g that are stocked in small brackishwater ponds at a stocking density of 1/m^2 or in individual cages for a period of 3–4 weeks while being fed thrice daily with trash fish at 5–10 percent of their biomass. Selective harvesting is done according to size, growth and demand, and the venture is profitable because of low operating costs and fast turnover. Monoculture (with single-size and multiple-size stocking) and polyculture with milkfish and mullets are being carried out on a small scale, as the seed supply is still mainly from the wild. Experiments on breeding and seed production of *S. tranquebarica* have given 20 percent survival rate from egg to first instar stage, and attempts are being made to improve the survival rate for an economically viable hatchery technology. Hatchery technology for breeding and seed production of the blue swimming crab, *Portunus pelagicus*, has also been developed and four generations of crabs have been produced by domestication. The hatchery seed is being utilized mainly for stock enhancement programmes along the east coast.

TABLE 11
Economics of three systems of mud crab farming (Source: ICAR, 2000)

Culture method	Monoculture	Polyculture	Fattening
Species	*Scylla tranquebarica, S. serrata*	*S. tranquebarica, S. serrata*	*S. tranquebarica, S. serrata*
Culture period (days)	120	138	30
Expenditure (seed, feed, pond, preparation, labour) (Rs)	43 860	48 400	56 200
Production (tonnes)	0.78	1.14 (and 0.7 milkfish)	0.56
Income (Rs)	157 200	261 200	122 850
Net profit /crop (Rs)	113 340	212 800	66 650

Edible oyster farming

CMFRI has developed methods for edible oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology that is presently being widely adopted by small-scale farmers in shallow estuaries, bays and backwaters along the coast. In the adopted rack method, a series of vertical poles are driven into the bottom in rows, on top of which horizontal bars are placed. Spat are either collected from the wild or produced in hatcheries, on suitable cultch materials. Spat collectors consist of clean oyster shells (5–6 shells) suspended on a 3-mm nylon rope at spaced intervals of 15–20 cm and suspended from racks close to natural oyster beds. Spat collection and further rearing is carried out at the same farm site, and a harvestable size of 80 mm is reached in 8–10 months. Harvesting is done manually and the production rate is 8–10 tonnes/ha. Oyster shells are also in demand by local cement and lime industry and culture production had increased to 800 tonnes in the year 2000.

Mussel farming

The raft method (in bays and inshore waters), rack method (in brackishwaters and estuaries) or longline method (in the open sea) are commonly adopted for farming mussels (*Perna indica* and *P. viridis*). Mussel seed of 15–25 mm size collected from intertidal and subtidal beds are attached to coir/nylon ropes of 1–6 m length and enveloped by mosquito or cotton netting. Seed attach to rope within a few days, while the netting disintegrates. The seeded ropes are hung from rafts, racks or longlines. A harvestable size of 70–80 mm is reached in 5–7 months, and a production of 12–14 kg of mussel (shell on) per meter of rope can be obtained. Attempts to demonstrate the economic feasibility of mussel culture have led to the development of group farming activities in the coastal communities (especially by rural women's groups) with the active support of local administration and developmental agencies like the Brackishwater Fish Farmers Development Agency (BFFDA) and the State Fisheries

Department. Cultured mussel production has increased from 20 tonnes in 1996 to 4 500 tonnes in 2004, mainly through use of the rack system in estuarine areas. Molluscan culture technologies and their economics are given in Table 12.

TABLE 12
Molluscan culture technologies and economics (Source: ICAR, 2000)

Technology	Edible oyster farming	Mussel farming	Pearl oyster culture
Species	*Crassostrea madrasensis*	*Perna viridis, P. indica*	*Pinctada fucata*
Farming method	Rack (30 x 10 m)	Raft (8 x 8 m)	Cages suspended from rafts/racks
Culture period	8 months	5–7 months	12–15 months
Unit area	300 m^2	64 m^2 & 600 box cages	Open sea; 6 rafts
Economics (US$)			
Initial investment	371	203	10 000
Recurring cost	139	357	4 419
Total cost	510	560	
Production	5.83 tonnes shell on (0.48 tonne meat)	0.8 tonnes shell on	
Revenue	736	934	Depends on percentage pearl production & market value of pearl
Profit	226	303	30% (at 25% pearl production)

Pearl oyster farming and pearl production

In India, marine pearls are obtained from the pearl oyster, *Pinctada fucata*. Success in the production of cultured pearls was achieved for the first time in 1973 by CMFRI. Raft culture and rack culture in nearshore areas are the two methods commonly adopted for rearing pearl oysters, and recently attempts have been made to develop onshore culture methods. Shell bead nucleus (3–8 mm) implantation is done in the gonads of the oyster through surgical incision, while graft tissues are prepared from donor oysters of the same size and age group. Implanted oysters are kept under observation for 3–4 days in the laboratory under a water flow-through system and then shifted to the farm in suitable cages for rearing. Periodic monitoring is done and harvesting is carried out after 3–12 months. Pearls are categorized into A, B and C types depending on colour, luster and iridescence. Twenty-five percent pearl production has been successfully demonstrated in a series of farm trials at various locations along the Indian coast. Research is also directed towards development of a technology for *in vitro* pearl production using mantle tissue culture of pearl oyster. The technology for mass production of pearl oyster seed and pearl production has paved the way for the emergence of pearl oyster farming as a profitable coastal aquaculture activity at certain centres along the coast. Village-level pearl oyster farming and pearl production, through direct involvement of small-scale fishermen, have been successfully carried out as part of a technology transfer programme along Valinokkam Bay on the east coast (Table 13). Pearl oyster farming has already generated income worth US$26 000, and several young women who are trained in pearl surgery in pearl farms are finding ready employment in this developing industry. CMFRI also imparts training on pearl culture to trainees in neighbouring Asian countries, and since 1996 several Memoranda of Understanding (MoU) have been signed with entrepreneurs interested in pearl culture. Recently success has been obtained in the production of Mabe pearls and the tissue culture of pearls. Success was achieved in the organ culture of mantle of pearl oyster and abalone. A breakthrough has been achieved by developing a tissue culture technology for marine pearl production using the pearl oyster *P. fucata* and the abalone *Haliotis varia* for the first time in the world. This technology can be easily extended to other pearl-producing molluscs and gives ample scope for manipulation of pearl quality and also increased pearl production. Mabe pearl production was standardized for production of base images with ten different types of moulds. Technology for production of jewellery from Mabe pearl was also standardized.

TABLE 13
Economics of the pearl culture programme at Valinokkam Bay – a group farming success

Number of oysters implanted	9 414
Total expenditure incurred (US$)	1 571
Rate of return (%)	56.7
Total pearls harvested	1 849
Revenue earned from sale of pearls (US$)	2 178
Pearls distributed to fisherman	250

Clam culture

A package of clam (cockle) culture practices has been developed for blood clam (*Anadara granosa* and *Paphia malabarica*), where production of 40 tonnes/ha in six months and 15–25 tonnes/ha in four to five months has been achieved in field trials. Induced spawning and larval rearing to setting of spat have been perfected for clams like *P. malabarica*, *Meretrix meretrix* and *Marcia opima*.

Sea cucumber culture

More than 200 species of sea cucumber are found in Indian waters, mainly in the Gulf of Mannar, Palk Bay and the Andaman and Nicobar Islands. The most important commercial species is *Holothuria scabra*, whose continuous exploitation has led to depletion of natural populations. Seed of *H. scabra* was produced in the hatchery for the first time in India in 1988 through induced spawning using thermal stimulation, and this technique has been widely used since then to produce seed for stock enhancement programmes. Water quality is the most important parameter in hatcheries, with ideal conditions being a temperature of 27–29 °C, salinity of 26.2–32.7 ppt, dissolved oxygen of 5–6 ml/litre, pH of 6–9 and ammonia content of 70–430 mg/m^3. The larvae require different diets at different developmental stages, and algae like *Isochrysis galbana*, *Chaetoceros calcitrans*, *Tetraselmis chuii* and *Sargassum* sp. are used. Seed produced in hatcheries are grown in velon screen cages (2 m^2 area), netlon cages (1.65 m^2 area, 5 mm mesh net), concrete rings (70 cm diameter x 30 cm height) and also at the bottom of shrimp ponds. Artificial diets prepared with soybean powder, rice bran and prawn-head waste are used for feeding juveniles and results are encouraging. Juveniles have been stocked at 30 000/ha and grown along with shrimp (*Penaeus monodon*) in farms. Sea cucumbers being detritus feeders, feed on waste shrimp feed and organic matter on the pond bottom, reducing the organic pollution load in the farm. Being an eco-friendly practice that also provides an additional income to the farmer, it is expected to become popular among farmers who have been facing problems of shrimp disease outbreaks in the recent past.

Marine finfish culture

In the area of marine fish culture, the country is still only in the experimental phase. Attempts are being made to develop suitable hatchery and farming technology for mullets (*Mugil cephalus*, *Liza macrolepis*, *Valamugil seheli*), groupers (*Epinephelus tauvina* and other species), Asian seabass (*Lates calcarifer*), milkfish (*Chanos chanos*) and pearlspot (*Etroplus suratensis*). The Central Institute of Brackishwater Aquaculture (CIBA) has developed an indigenous hatchery technology for seabass using captive broodstock that were stocked in large reinforced concrete cement (RCC) tanks (12x6x2 m) with 70–80 percent water exchange daily. The maturation process was accelerated using luteinizing hormone-releasing hormone (LHRH) injection and larvae were maintained with rotifers and *Artemia* nauplii. Cooked and minced fish meat is used for nursery rearing, and survival rates of up to 14 percent in the larval rearing phase and 84 percent in the nursery phase have been recorded. Hormonal induction of broodstock development was achieved in groupers.

Ornamental fish culture

There are a wide variety of ornamental fish in the vast waterbodies and coral reef ecosystems along the Indian coast that, if judiciously used, can earn a sizeable foreign exchange. A long-term sustainable trade of marine ornamental fishes can be developed only through hatchery-produced fish. Hatchery technology for clownfish (*Amphiprion sebae*), damsel fishes (*Pomacentrus caeruleus*, *Neopomacentrus nemurus, N. filamentosus*, *Dascyllus trimaculatus*) and sea horse (*Hippocampus kuda*) has been developed and could be scaled up for mass production.

Seaweed culture

Around 60 species of commercially important seaweeds with a standing crop of 100 000 tonnes occur along the Indian coast, from which nearly 880 tonnes of dry agarophytes and 3 600 tonnes of dry alginophytes are exploited annually from the wild. Seaweed products like agar, algin, carrageenan and liquid fertilizer are in demand in global markets; and some economically viable seaweed cultivation technologies have been developed in India by CMFRI and the Central Salt and Marine Chemical Research Institute (CSMCRI). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweed collected from natural beds or by spores (tetraspores/carpospores). Seaweed culture has the potential to develop in large productive coastal belts and also in onshore culture tanks, ponds and raceways. Recently the culture of the carrageenan-yielding seaweed *Kappaphycus alvarezii* has become very popular and this species is being cultivated extensively along the Mandapam coast. To make the seaweed industry more economically viable, research aimed at improvement of strains of commercially important species by isolating viable protoplasts and somatic hybridization techniques is being carried out. The rate of production of *Gelidiella acerosa* from culture amounts to 5 tonnes dry weight per ha, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per ha. Pilot-scale field cultivation of *K. alvarezii* carried out in the nearshore area of Palk Bay and Gulf of Mannar showed maximum increase in yield of 4.3 fold after 30–32 days in Palk Bay and of 5.7 fold after 22–34 days in the Gulf of Mannar.

PRIORITIES FOR DEVELOPMENT AND RESEARCH

Seed production of crabs, lobsters, cephalopods and marine finfish

The lack of availability of seed for commercial-level farming is the major constraint to the development and expansion of mariculture in India. Hence maximum research thrust is required for the development of commercial seed production technologies for the suitable species of crabs, lobsters and marine finfishes. Even though seed production of swimming crab (*Portunus pelagicus*) has been achieved, the survival rate to the seed stage is only about 5 percent. Improvement of technology is thus required to achieve commercial-level seed production. Similarly, success in seed production of the sand lobster (*Thenus orientalis*) also remains to be scaled up to commercial level. In the case of spiny lobsters, the larval rearing to phyllosoma VIII still remains a challenge due to the prolonged larval phase. The experimental success obtained in the seed production of squids and cuttlefishes (*Loligo singhalensis, Sepia pharaonis, S. lessoniana* and *S. inermis*) has to be scaled up. Massive research input is required for development of seed production technologies for the many species of marine finfish that are suitable for open sea-cage farming.

Open-sea cage culture

Open-sea cage culture has been expanding on a global basis and is viewed by many stakeholders in the industry as the aquaculture system of the future. Cage culture has made possible the large-scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of raising fish. It is now recognized that further conversion of wetlands and mangroves into traditional aquaculture farms has to be limited. Cage culture has several advantages over other culture systems. The cage-culture system can optimize the carrying capacity per unit area, since the flow of current brings in fresh water and removes metabolic wastes, excess feed and faecal matter, although the risk of self pollution must be reduced through good management and site selection. Simple cages for inshore waters are relatively easy to construct with minimal skilled labour. The Indian coast offers many ideal locations for cage farming, potential sites including bays in Ratnagiri, Goa, Karwar, Palk Bay, Larsons Bay, Gulf of Mannar, Lakshadweep islands and the Andaman and Nicobar Islands. Potential fish for cage culture include groupers, snappers, seabass, rabbitfish and *Cobia*. A few modern demonstration farms could be set up at suitable sites by entrusting the work to developmental agencies of the central and state governments. The materials for cage farms and the technology for installation of floating cages could be imported. Floating cage farming can be further expanded after its techno-economic viability under Indian conditions is established through the demonstration farms. The traditional practice of artisanal cage farming can also be improved and expanded by extension and training programmes to fishermen by central and state government developmental agencies.

Popularization of bivalve mariculture

Being in the lower part of the food chain, bivalves are energy efficient and cause minimal pollution to the culture system and the environment. Bivalve culture can be carried out as an artisanal activity and also as a large-scale mariculture enterprise oriented towards the export market. Artisanal mariculture of mussels, edible oysters and clams is being practiced on a small scale in certain parts of the Indian coast. There is scope for bivalve farming along the Kerala, Karnataka and Konkan coast. State and central government developmental agencies can be entrusted with the expansion of bivalve farming in suitable coastal areas by providing training and extension programmes. Large-scale industrial farming of bivalves can also be taken up with an export-oriented market.

Expansion of seaweed culture

The seaweed industry provides a wide variety of products that have an estimated total annual production value of US$5.5–6 billion. Food products for human consumption contribute about US$5 billion to this figure. Substances that are extracted from seaweeds – hydrocolloids – account for a large part of the remaining billion dollars, while smaller miscellaneous uses, such as fertilizers and animal feed additives, make up the rest. The industry uses 7.5–8 million tonnes of wet seaweed annually, harvested either from naturally growing (wild) seaweed or from cultivated (farmed) crops. The farming of seaweed has expanded rapidly, as demand has outstripped the supply available from natural resources. Commercial harvesting occurs in about 35 countries, spread between the northern and southern hemispheres, in waters ranging from cold through temperate to tropical. In this context, mariculture of seaweeds in suitable coastal areas has to be promoted to industrial-level production. Suitable areas for seaweed culture include the Tamil Nadu coast, Orissa coast, Okha Veraval coast and Konkan coast. Demonstration programmes for artisanal seaweed culture could be organized by developmental agencies in this area. Large-scale culture of seaweed can also be demonstrated at

Palk Bay to assess the techno-economic viability for industrial-level production of seaweeds. Production of good quality agar/carrageenan and development of an appropriate marketing system have to be taken up as priority programmes for the development of the seaweed industries in India.

Demonstration farms for pearl culture

The techno-economic viability of pearl culture still remains to be demonstrated in India. Hence establishment of one or two demonstration farms through central/state developmental agencies is the immediate requirement before commercialization of this programme can proceed.

Development of artisanal mariculture programmes

Since the marine fish catch in recent years has been declining, alternate small-scale livelihood programmes have to be evolved for coastal fishermen. In this context, artisanal mariculture can play a vital role as an additional source of income. Artisanal mariculture of bivalve molluscs and seaweeds, and crab and lobster fattening are being practiced in certain parts of the coast. Extensive training programmes could be organized along the coasts of Kerala, Tamil Nadu, Karnataka, Konkan and Orissa for promoting artisanal mariculture practices.

Marine ornamental fish trade through hatchery production

In recent years, the marine ornamental fish trade has become a global industry worth an estimated US$200–330 million annually and operated throughout the tropics. Even though India is bestowed with good ornamental fish resources, wild collection from coral reefs can lead to destruction of the reef habitat. Hence development of trade through hatchery production of fish offers potential. In the recent past, CMFRI has developed hatchery production techniques for clownfish and a few damsel fish species. However the techno-economic viability of commercial-level production is yet to be demonstrated. Hence establishment of one or two demonstration units at suitable areas like Lakshadweep, the Andaman and Nicobar Islands and the Gulf of Mannar coast is required through state and central developmental agencies. In addition, research on development of seed production technologies for suitable species of marine angelfishes, gobiids and cardinal fishes deserves attention.

Establishment of seed banks for mariculture

The availability of seed is a basic requirement for any commercial mariculture enterprise. At present, except for a few species of shrimp, commercial-level seed availability is lacking for species suitable for mariculture. Hence the establishment of seed banks at appropriate locations is the basic requirement for the development of mariculture. For those species for which hatchery production of seed is not economically viable (e.g. bivalves) or hatchery production technologies are not available (many species of marine finfish), seed banks could be developed from wild-collected seed. Lack of commercial-level hatchery production technologies is the major constraint for the development of marine aquaculture in India. Hence research on seed production for species having culture potential should be strengthened.

Integrated farming of finfish and shellfish with seaweed

Integrated farming of fish and shellfish with seaweed can reduce the environmental impact of industrialized mariculture and at the same time add to its income. Plants counteract the environmental effects of the heterotrophic-fed fish and shrimp and restore water quality. A 1 ha land-based integrated seabream – shellfish – seaweed farm can produce 25 tonnes of fish, 50 tonnes of bivalves and 30 tonnes fresh-weight of seaweeds annually. Hence modern integrated systems are bound to play a major role in the sustainable expansion of mariculture. A few demonstration farms on integrated farming of fish and shellfish with seaweed can be established at suitable locations through central/state developmental agencies to assess the techno-economic viability.

Installation of artificial reefs and FADs

Artificial reefs and Fish Aggregating Devices (FADs) are known to attract fish. Hence their installation in suitable areas of the coast can enhance fish production. A few artificial reefs and FADs can be installed at suitable locations by central/state developmental agencies involving fisherfolk participation. Regular assessment of the impact of artificial reefs and FADs on enhancing fish production can be done with the involvement of research institutions.

Large-scale sea ranching for stock enhancement

As the overexploitation of many of our marine fisheries resources has lead to a reduction of wild stocks, large-scale sea ranching programmes may play a vital role in natural stock enhancement. Sea ranching of *Penaeus semisulcatus* is already being carried out in the Mandapam area by CMFRI. A massive sea-ranching programme for *P. semisulcatus* can be taken up along the east coast by developmental agencies through fisherfolk participation. Regular impact assessments of sea ranching have to be conducted by involving research institutions.

Development of capture-based aquaculture

Capture-based aquaculture (CBA) has been defined as the practice of collecting "seed" material – from early life stages to adults – from the wild, and its subsequent grow out to marketable size in captivity using aquaculture techniques. This category of farming includes the rearing of some species of finfish and molluscs and certain forms of extensive shrimp culture. It is estimated to account for about 20 percent of the total quantity of foodfish production through aquaculture. Using FAO data from 2001, this is equivalent to over 7.5 million tonnes per year, and is principally molluscs. The production of finfish, especially carnivorous species (including groupers, tunas, yellowtails and eels), through CBA is currently receiving the most attention. CBA is an interface between capture fisheries and true aquaculture and provides an alternative livelihood for local coastal communities in developing countries and several industrialized nations. In India, since the seed production technologies of many species are either not standardized or are not commercially viable, CBA might be developed, with proper management.

Conservation mariculture

The populations of many marine species are in decline and are in the process becoming endangered. These include species of *Trochus, Turbo,* chank, sea cucumber and sea horse. Stock replenishment through large-scale seed production and sea ranching will be a positive step towards the conservation of these species. CMFRI has successfully developed hatchery techniques for some of the species; however, future research on such approaches is very much warranted.

Identification of better management practices (BMPs) and systems to mitigate environmental impacts

The following BMPs are suggested for bivalve culture and seaweed culture. Extensive information has been generated on BMPs for shrimp farming, and is therefore not included here.

Bivalve farming
Plants counteract the environmental effects of the heterotrophic-fed fish and shrimp and restore water quality. Hence integrated farming of finfish and shellfish with seaweeds will prove to be more ecologically sustainable, in addition to being more productive.

Seaweed farming
Seaweed culture is presently carried out in coastal waters using bamboo rafts. If many rafts are deployed in the same area, it would not only adversely affect nutrient availability and phytoplankton production, but also fisheries, movement of boats, fishing operations, traditional rights, etc. Thus proper siting needs to encouraged, and suitable areas should be identified for seaweed farms. Also, the culture ropes can be integrated with the mussel culture rafts, as is already done by mussel farmers in the Kasargod area. This approach will help to a great extent in preventing mussel farms from adversely affecting the culture sites, as nutrient output from mussels can be absorbed. The growth rates of seaweeds in such farms are several folds higher. A package should be developed along these lines to establish environmentally friendly mussel-oyster-seaweed farms along the coasts.

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MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKET

Indonesia has 5.8 million km^2 of marine area, with 17 504 islands and 81 000 km of coastline, and a population of 217 million people. National export of fisheries product in 2004 was 902 358 092 kg valued at US$1 780 million (about 2.69 percent of total export value), while national import of fisheries product in the same period was about 136 040 149 kg with a value of US$154 million (about 0.28 percent of total import). Export volume and value of fisheries product by commodity are shown in Table 1.

TABLE 1
Export volume and value of fisheries product by commodity in 2004

Commodity	Volume (kg)	Value (US$)
Fresh shrimp, frozen, canned	139 450 184	887 127 117
Fresh tuna, frozen, canned	94 220 950	243 937 896
Other live, fresh, frozen, dried, canned	522 831 403	354 446 044
Fresh crab, frozen, canned	20 902 586	134 354 913
Frog leg	3 388 995	11 515 497
Dried jellyfish	4 598 934	4 994 686
Snail	1 886 462	2 762 606
Shrimp crisp	5 535 502	7 539 046
Fish oil	2 141 066	637 748
Dried seaweeds	51 010 828	25 296 399
Coral and shell	3 125 494	1 411 077
Pearl	1 711	5 866 158
Ornamental fish	3 516 060	15 809 284
Dried anchovy	3 202 761	18 571 267
Other product	46 545 156	66 563 069
Total	902 358 092	1 780 832 807

Total production of capture fisheries is about 4.07 million tonnes/year, and total production of aquaculture in 2004 was 1.47 million tonnes (Table 2) (about 26 percent of total fishery production).

TABLE 2
Indonesian aquaculture production in 2004

Aquaculture system	Production (tonnes)
Marine-based aquaculture	420 919
Coastal brackishwater pond	559 612
Inland pond	286 182
Freshwater cage culture	53 695
Freshwater floating net	62 371
Rice field integrated farming	85 832
Total	1 468 610

The contribution of mariculture to fisheries production in 2004 was about 0.42 million tonnes (Table 3) or about 28.6 percent of total aquaculture.

TABLE 3
Indonesian mariculture production by commodity in 2004

Commodity	Production (tonnes)
Grouper	6 552
Asian seabass	1 748
Mussel	12 953
Seaweeds	397 964
Other	1 702
Total	420 919

Almost all Indonesian mariculture products are produced for export. Grouper, Asian seabass and other finfish are commonly exported as live fish. They are transported from the farm by live-fish transport with seawater circulation. Seaweed products for carageenan extraction are exported as dried raw materials. The trading of this bulky product involves several marketing intermediaries before export.

The cost of transport from farming sites to buyers remains a marketing constraint for seaweed. A collector is needed who is able to bring together sufficient quantities of seaweed and transport them efficiently to the larger buyers. Some intermediate steps require quality and price adjustment before seaweed is ready to export. Quality assurance along the trading chain is also required, with reasonable prices for farmers and traders.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

Indonesia has identified 12 139 042 ha of area available for marine aquaculture (excluding coastal ponds); however, as of 2004 only about 1 227.49 ha (0.01 percent) was used. If the effective area (based on receiving capacity) is about 10 percent of the available area, the optimal area is about 1.2 million ha of potential farming area.

The Indonesian Archipelago has tropical characteristics with various rainfall patterns. The western part of Indonesia has an annual rainfall of more than 2 000 mm with a longer rainy season and lower solar radiation. The eastern part of Indonesia is rich with solar radiation and has lower precipitation and shorter periods of rain. The western part is therefore considered to have higher suitability for agriculture and brackishwater aquaculture, while the eastern part is considered suitable for mariculture. The potential area available for mariculture development in Indonesia is given in Table 4, along with data on the distribution of poverty in the country.

TABLE 4
Poverty distribution and suitable mariculture area available in Indonesia

Province	Number of poor (x1 000)	Population (%)	Available mariculture area (ha)	2004 area (ha)
Nangroe Aceh D	1 157.2	28.47	129 318	-
Sumatera Utara	1 800.1	14.93	99 642	0.24
Sumatera Barat	472.4	10.46	54 139	15.14
Riau	744.4	13.12	118 377	0.55
Jambi	325.1	12.45	290 205	-
Sumatera Selatan	1 379.3	20.92	614 834	-
Bengkulu	345.1	22.39	9 258	-
Lampung	1 561.7	22.22	388 351	0.51
Bangka-Belitung	91.8	9.07	255 175	9.95
DKI Jakarta	227.1	3.18	2 825	2.40
Jawa Barat	4 654.2	12.10	35 933	11.00
Jawa Tengah	6 843.8	21.11	1 134	-
D.I. Yogyakarta	616.2	19.14	0	-
Jawa Timur	7 312.5	20.08	31 937	30.00
Banten	779.2	8.58	60 768	9.28
Bali	231.9	6.85	8 140	421.00
Nusa Tenggara Barat	1 031.6	25.38	139 523	251.00
Nusa Tenggara Timur	1 152.1	27.86	160 922	3.01
Kalimantan Barat	558.2	13.91	853 640	0.21
Kalimantan Tengah	194.1	10.44	659 754	-
Kalimantan Selatan	231.0	7.19	199 467	5.86
Kalimantan Timur	318.2	11.57	409 314	2.62
Sulawesi Utara	192.2	8.94	43 105	304.00
Gorontalo	486.3	21.69	65 836	0.27
Sulawesi Tengah	1 241.5	14.90	551 235	0.31
Sulawesi Selatan	418.4	21.90	43 028	-
Sulawesi Tenggara	259.1	29.01	183 911	149.30
Maluku	397.6	32.13	1 065 983	9.85
Maluku Utara	107.8	12.42	429 154	0.18
Papua	966.8	38.69	5 234 074	0.8
Total	36 146.9	16.66	12 139 042	1 227.49

The total number of poor is about 36.14 million (16.7 percent of the population), while the potential area used for mariculture is about 0.01 percent. This raises the question, "Is mariculture able to reduce poverty?" The Government of Indonesia strives to provide the proof that the answer is an optimistic, "yes".

The area used for mariculture has increased annually by an average of about 19.4 percent since 2000, while the annual increase in the number of farmers over this period has averaged 30.7 percent (Table 5). There seems to be significant mariculture development; however, the area utilized is still very low compared to that available.

TABLE 5
Number of farmers involved in mariculture and total area utilized, 2000–2004

Year	Number of farmers	Total area utilized (ha)
2000	29 604	614
2001	39 800	713
2002	65 624	951
2003	67 735	981
2004	81 377	1 227
Average annual increment	30.7 %	19.4%

The range of species cultured in the Indonesian mariculture sector is still limited and is dominated by export-oriented commodities. The oldest commodity is seaweed, which has been exported since 1985 from several areas around the country. In 2004 the quantity of dried seaweeds (*Eucheuma cottonii* or *Kapaphycus alvarezii*) exported was about 400 000 tonnes from around 3.2 million tonnes of farm-harvested product. The development of seaweed farming has been successful, but its expansion is also limited by factors such as the need to identify suitable areas and a lack of information about value, culture techniques, markets and capital. The area suitable for seaweed culture has been recognized only after some on-site trials; however, there is still a lack of systematic analysis of suitable locations. Spatial and temporal variation in environmental conditions is not always detectable by conventional analyses without year-round sampling.

The development of seaweed farming has helped reduce poverty in several areas of Indonesia and provides several lessons for successful mariculture:

- The target location should be feasible for farming of commercial strains/species on a commercial scale. Site suitability is only recognizable after on-site trials.
- The introduction of farming requires a "candidate farmer" who should be able to work successfully under the conditions found in coastal areas.
- The seed (initial stock) and other facilities provided to farmers should be provided as a "loan" that should be paid back after a certain period of successful harvests.
- Supervision should be provided to the farmer and continued until marketable quality seaweed is produced in sufficient quantity.
- Farmers should be "connected" with a "generous" trader or exporter.

Government, through so-called "Technical Implementation Units" (TIUs), has started to facilitate initial seaweed stock plantations in several regions, in order to ensure farmers that the initial stock is available and can be obtained at a reasonable price. The Marine Aquaculture Development Centre of Lombok has also built up a multistrain stock of seaweeds.

The other aquaculture commodity that has shown significant recent growth is finfish, particularly grouper. This commodity is considered harder to develop for poverty alleviation, as poor farmers are limited by technology, capital and market information.

Grouper seed became available from commercial hatcheries in 1999, along with commercial pelleted feed in 2003. Although farmers produced 6 552 tonnes of marine fish in 2004, considerable problems still remain. Unsuccessful examples of grouper development have been experienced in Indonesia, providing the following lessons:

- Risks due to mortality and market are now considered as major constraints.
- There is a lack of practical management practices and demonstrations to help farmers in controlling mortality due to diseases caused by parasites and other pathogens.
- It takes a long time for tiger grouper and humpback grouper to reach marketable size (about 10 months and 16 months, respectively). This long culture period increases investment risk.

- Trading live fish is difficult and risky and needs a large production scale.
- High capital investment is unattractive to investors.

The culture of pearl oyster is also one of the established mariculture activities in Indonesia. The Indonesian Pearl Culture Association has 39 registered pearl oyster company members. Excluded from the association are more than 100 small companies or smallholders involved in pearl farming. The pearl farms are located in Lampung (Sumatera), Madura (East Java), Bali, West Nusa Tenggara, Sulawesi, Maluku and Papua. As of September 2005, they produced 3 800 kg of pearl. The species available in Indonesia are: *Pinctada maxima, P. margaritifera, P. fucata, P. lentiginosa* and *Pteria penguin.* So far, the wild broodstock appears to be sufficient to fulfil the hatchery requirements.

Pearl farms employ plenty of labour, contributing to poverty alleviation, but the employment is not socially secure. Security risks are one of the main problems faced by pearl farming. The rearing activity in open water is hard to control. Security problems may indicate social problems with the local community. Companies should seek to involve the local community to minimize such problems, and business interdependency between the local community and the company should be created through mutual collaboration.

Pearl farming requires several independent processes including:

- hatchery operations for producing spat;
- nursery operations to raise spat to young oysters (5 cm shell length) at 6 months after stocking;
- rearing to produce adult oysters (10 cm length), that are ready for nucleus insertion; and
- insertion and incubation of inserted oysters to produce pearls.

It is recommended that spat production usually be conducted by government hatcheries, which are able to supply sufficient spat; nursery operations and rearing to adult oysters can be conducted by the local community and supervised by the company or government. Insertion of nucleus and incubation to produce pearls is conducted by the company. Such arrangements are advantageous to the company, as they minimize hired labour and assure protection of the company's investment by the community because there is a mutual interest in success. There are working examples of such collaboration in Indonesia.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Indonesia has institutions for mariculture development that are spread from the west to the eastern part of the country. They are called Technical Implementation Units (TIUs), and are part of the Directorate General of Aquaculture. Such institutions include:

- Center for Marine Aquaculture Development, Lampung (Sumatera)
- Marine Aquaculture Development Center, Batam (Riau)
- Marine Aquaculture Development Center, Ambon
- Marine Aquaculture Development Center, Lombok (West Nusa Tenggara)
- Brackish Water Aquaculture Development Center, Jepara (Central Java)
- Brackish Water Aquaculture Development Center Takalar (South Sulawesi)
- Brackish Water Aquaculture Development Center, Situbondo (East Java)
- Brackish Water Aquaculture Development Center, Aceh

The mission of the TIUs is to conduct technology propagation/extension and develop applied technology. They have facilities such as commercial-scale experimental facilities (hatchery, nursery and grow-out facilities), training facilities, dormitories and laboratory services. The technology transfer by these institutions usually involves:

- on-the-job training, where participants stay, learn and work with the staff in charge for a certain period, depending on the subject and level;
- publication of posters and leaflets;
- on-farm supervision; and
- pilot projects, prototype testing and modelling.

For example, one of the current activities conducted at the Marine Aquaculture Development Center in Lombok is training on abalone culture for vocational schools involved with marine aquaculture. The training involves teachers from seven provinces with the purpose of accelerating abalone spat production.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGY

Indonesian mariculture involves the culture of seaweeds, grouper, lobster and abalone. Seaweeds (*Eucheuma* spp.), as one of the established species, is recognized as a strategic commodity. Its culture involves large numbers of people, applies simple techniques and provides short-term returns to farmers for small investment. The existing seaweed producers are located in seven provinces, i.e. Sulawesi Utara, Sulawesi Tenggara, Sulawesi Selatan, Jawa Timur, Bali, Nusa Tenggara Barat and Nusa Tenggara Timur. Both floating and off-bottom farming methods are used. Seaweed farming areas produce 40 tonnes of harvest per ha per month. The Indonesian government supports development of this commodity by encouraging cooperation among capital sources (banking) for credit, companies for marketing and processing and the coastal community as a seaweed producer.

The technology for grouper (tiger and humpback) farming was first established in 1999 and has developed rapidly since then. Hatchery seed is now available from Lampung, East Java and Bali. Private companies entered the business in 2002 and are mainly located at Lampung, Nusa Tenggara, Bali and Riau. Fish-farming companies located close to a source of trash fish have a comparative advantage, with feed provided by fishers at lower prices and in relatively fresh condition. The main problems with grouper production relate to trading and marketing. The main markets for grouper (People's Republic of China and China, Hong Kong SAR) require live fish. The high risk and transportation costs influence the competitiveness of the product from Indonesia. Diseases due to parasites and other pathogens are also a problem.

Grouper farming has been introduced to small households by government in several provinces, but with limited success due to technical and non technical constraints. Major concerns appear to be the long grow-out period and the need for regular investment by farmers in trash fish for feed without returns from fish sales.

Lobster is a mariculture commodity that can generate income within a short period. Floating cages stocked with 50-g adolescent lobster (*Panulirus* spp.) and fed with trash fish can reach 250 g within 6 months. Lobster culture is conducted by smallholders located close to the source of wild seed. However, the capture of wild lobster seed needs to be controlled to preserve broodstock and limit overharvesting. At present, wild seed of 2–3 cm are collected by fisherman using artificial aggregators (settling media) made of fibre sack or cotton cloth. Wild seed can easily be collected during the period of settling. The collected juveniles are nursed in concrete tanks or floating nets and fed with trash fish until they reach a length of 5 cm, after which they are transferred to grow-out facilities. Lobster mariculture, including the nursery step, shows potential for further development and is currently under experimentation.

Abalone, especially tropical abalone (*Haliotis asinina*), is another commodity with potential for further development. Experiments show that the animal can be raised in floating cages, obtaining a marketable size (7 cm shell length) in 12 months. They are fed with seaweeds (*Gracilaria* spp. and *Ulva* spp.) and show a survival rate of about 50 percent and a food conversion ratio (FCR) of 1:15. The technique to produce seed (spat) in hatcheries is available, but there are no private hatcheries as yet in Indonesia to provide sufficient spat. The government should invest or encourage private investment in hatcheries to produce abalone seed. Abalone culture also has potential for integration with grouper or seaweed farming.

Green mussel (*Perna viridis*) culture is established around the Gulf of Jakarta, with about 10 000 tonnes produced annually. Farmers use bamboo sticks to settle the spat. The main problems are poor water quality and toxic algae in coastal waters arising from urban pollution. The Indonesian government is concerned about these problems and is involved in transplantation of mussel spat to less polluted areas. The Centre for Mariculture Development at Lampung has also successfully produced hatchery spat.

Islamic Republic of Iran

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BACKGROUND

The Islamic Republic of Iran has a great potential for fisheries development activities, with some 1 850 km of coastline in the south (the Sea of Oman and Persian Gulf) and over 900 km of coastline in the north (the Caspian Sea). Iran IR comprises a land area of 1.64 million km^2 and is located in the northern part of the temperate zone between latitudes 25°00 and 39°47’ north and longitudes 44°02’ and 63°02’ east. The average altitude is over 1200 m. The Islamic Republic of Iran is bordered by Turkmenistan, the Caspian Sea, Azerbaijan and Armenia on the north; Afghanistan and Pakistan on the east; the Sea of Oman and Persian Gulf on the south; and Iraq and Turkey on the west. The country has three main climatic zones where several different fish and shrimp species can be grown:

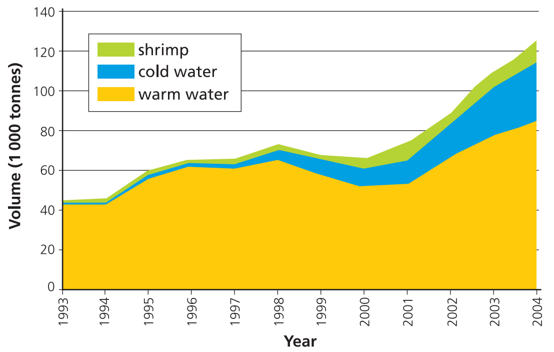
- arid and semi-arid regions of the interior and far south, characterized by long, warm and dry periods, lasting sometimes over seven months, covering nearly 90 percent of the country and having an annual precipitation rate of between 30 and 250 mm;
- Mediterranean climate (mainly in the western Zagros Mountains, the high plateau of Azerbaijan and the Alborz Mountains), characterized by warm, dry summers and cool, damp winters, with annual rainfall between 250 and 600 mm, and covering about 5 percent of the land surface; and
- humid and semi-humid regions (mainly in the Caspian, but also in west Azerbaijan and the southwest Zagros), with an annual precipitation rate of 600 to 2 000 mm, also covering about 5 percent of the land surface.

Although aquaculture in Asia dates back thousands of years, there has been limited attention to its development in Iran IR until the last four decades. The first aquaculture experiment was conducted with rainbow trout culture near Tehran in Mahisara (Karaj) in 1959. The first farm for warmwater aquaculture was established in Giulan Province and by the Abzi Company in Khuzestan Province (Shooshtar) in 1971. Shrimp culture in Iran IR has a short history, occurring only since 1991. The industry has developed very rapidly over the past seven years and great progress has been made (Shakouri, 2003).

STATUS OF IRANIAN AQUACULTURE

The Government of Iran considers the fisheries sector as important for job creation, food security and poverty alleviation in the 4th National Five-Year Development Plan (NFDP). In 2003 some 144 600 employees were directly involved in the sector. Fisheries products provide 2.7 g/day per capita of animal protein supply in the country (Abdolhay, 2005). While fisheries production exceeded 440 000 tonnes in

Figure 1
Aquaculture production, 1993–2004



2003, the government has targeted a production of 763 000 tonnes in 2009. This means that the fish supply will increase from 6.1 to 10 kg per capita and will provide 4.5 g of animal protein. Fish is an expensive, high-status food item in the Islamic Republic of Iran. The consumption in the Islamic Republic of Iran is 6.1 kg per capita (Shilat, 2003), and the main goal of the government is to increase fish consumption to 7 kg (for comparison, world per capita fish consumption is 13.5 kg). Faced with population trends and the decline of some capture fisheries, the government is increasingly looking at aquaculture as an alternative source of fish and shellfish products, and a contributor of animal protein to food security by raising fish consumption to 13.5 kg per capita.

The total fisheries and aquaculture production in 2003 was 442 000 tonnes (Shilat, 2003). The goal of the government is to achieve a production of 100 000 tonnes of farmed marine fish in the Persian Gulf, Oman Sea and the Caspian Sea. Since 1990 the Islamic Republic of Iran has increased shrimp farming, which now has a yearly production of 4 000 tonnes. There are plans for increasing shrimp production to 47 000 tonnes by 2009 from an area of 22 000 ha.

Fingerlings of several species are produced and stocked in the Caspian Sea and Persian Gulf. In 2004 a total of 235 million fingerlings were released into these seas (Abdolhay, 2005). There are currently no selection or breeding programmes on any of these species for restocking purposes, although there are plans for such a programme for both shrimp and the Caspian trout (*Salmo trutta caspius*). The total aquaculture production trends are shown in Figure 1.

CULTURE SPECIES

Warmwater fish culture includes the extensive rearing of four Chinese carps, namely common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*). The species were introduced from Romania, Hungary and the People's Republic of China. Coldwater fish farming includes rearing of rainbow trout (*Oncorhynchus mykiss*) in tanks and raceways. Rainbow trout were introduced from several countries, including the United Kingdom, Italy and Norway.

Shrimp-farming systems are semi-intensive, aiming at a production of 3 tonnes/ha in rectangular, earthern ponds. *Fenneropenaeus indicus* is the main species cultured because of the availability of wild spawners, its easy maturation in captivity and its tolerance of various environmental conditions (salinity in particular). Several experiments have shown that green tiger shrimp (*Penaeus semisulcatus)* and banana shrimp (*F. merguiensis)* are not reliable species for pond culture. Slow growth of *P. semisulcatus* and high mortality of *F. merguiensis* are main disadvantages of these species.

Farming of freshwater prawn (*Macrobrachium rosenbergii)*, beluga (*Huso huso*), common bream (*Abramis brama*), milkfish (*Chanos chanos*), barb (*Mesopotamichthys sharpeyi*) and pike-perch (*Sander lucioperca*) has been introduced to farmers for diversification of production and to provide more flexibility in marketing.

Shrimp culture

In 2002, the Islamic Republic of Iran produced 5 960 tonnes of shrimp in 246 farms. Compared to the previous year, the production and number of farms showed a 20 per-cent and 12 percent decrease, respectively. The reason for this decline was the low price of shrimp in the world market and a disease outbreak in one farm complex (Choebdeh farm complex, Khuzestan) (Table 1). In spite of the control of disease in Khuzestan, the farms are still closed. Production of pond-reared shrimp in 2004 was 8 902 tonnes. Table 2 shows the number of shrimp postlarvae that have been produced in shrimp hatcheries from 1994–2004.

TABLE 1
Number of farms, pond area and annual production of shrimp, 1992–2004

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Number of farms	2	11	12	37	40	60	79	138	207	278	207	249	310
Pond area (ha)	2	31	47	179	181	440	612	1 336	2 461	3 618	2 647	3 589	4 098
Production (t)	3	16	53	135	159	518	865	1 827	4 005	7 606	5 960	7 500	8 902

TABLE 2
Production of shrimp postlarvae (millions), 1994–2004 (Source: Shilat, 2003)

Species	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
F. indicus	282.0	18.0	24.7	57.0	114.0	306.0	532.0	828.0	683.0	764.3	900.8

STOCK ENHANCEMENT

Fish stock enhancement

One of the main goals for Shilat is to preserve and maintain the diversity of species in the Caspian Sea and Persian Gulf. In the last 10–20 years, severe stock depletion for several species has led to restocking programmes, with annual releases of about 250 million fry and fingerlings into the Caspian Sea and Persian Gulf (Table 3). The releases are an important event for the whole community (Abdolhay, 2005).

TABLE 3
Releases of fingerlings (millions) to the Caspian Sea and Persian Gulf for stock enhancement, 1994–2005

	Species	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Caspian Sea	Sturgeon	4.66	8.05	11.0	18.8	22.6	19.1	18.3	20.0	19.6	20.0	21.1	10.0
	Kutum	142.7	117.9	142	154	143	148	147	232	225	155	179	229
	Caspian salmon	0.64	0.80	0.42	0.34	0.51	0.50	0.64	0.36	0.34	0.33	0.31	0.3
	Bream	10.4	11.2	8.40	12.9	13.8	14.2	14.3	15.5	16.5	17.0	16.3	27.1
	Perch	2.88	2.27	2.41	5.43	3.61	4.00	4.00	7.40	5.50	11.0	7.54	10.2
	Sea carp	0	0	0	6.50	24.0	9.00	32.0	17.9	7.60	2.00	0.0	0.3
	Caspian roach	0	0	0	15.8	13.9	10.7	16.2	19.1	12.2	12.0	10.4	3.8
Persian Gulf	Yellow seabream	-	-	-	-	-	-	-	-	-	-	0.05	0.6
	Gray grouper	-	-	-	-	-	-	-	-	-	-	-	0.1
Total (rounded)		161	140	164	214	221	206	233	312	287	217	235	282

The decrease of some species in 2005 compared with the previous year is a result of the lack of wild broodstock.

Shrimp stock enhancement

Table 4 shows the number of shrimp postlarvae released in the northern part of the Persian Gulf and the Oman Sea during the years 1997–2005.

TABLE 4
Number of shrimp postlarvae released into the Persian Gulf and Oman Sea, 1997–2005

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Number (x1 000)	7 049.5	2 085	4 200	1 998.5	4 630	5 750	13 696.7	72 703	9 095.7	121 208.4

MARINE CAGE CULTURE

With the assistance of the Refa Company (a Norwegian company), Shilat studied the feasibility of marine fish farming in the northern coast of the Persian Gulf, Oman Sea and the southern coast of the Caspian Sea. The results show a good potential for cage culture in various areas.

The major candidates for cage culture are silver pomfret (*Pampus argenteus)*, milkfish (*Chanos chanos)*, cobia *(Rachycentron canadum)*, Asian seabass (*Lates calcarifer*), rabbitfish (*Siganus* sp.) and gilthead seabream (*Sparus aurata*) in the Persian Gulf and Oman Sea. For the Caspian Sea, major candidates are considered to be beluga (*Huso huso*), rainbow trout and the local trout (*Salmo trutta caspius*).

The study estimated the potential for cage culture as 200 000 tonnes for the central, 10 000 tonnes for the western and 40 000 tonnes for the eastern part of the Caspian Sea. The potential for Persian Gulf cage culture was estimated as 150 000 tonnes (excluding Khouzestan Province).

There is significant potential for the development of a viable marine fish culture industry based on sea-cage production systems in Iran IR. Application of available technical and financial resources to establish pilot and commercial cage-farm facilities is a priority to meet the ambitious goal of developing the sea-cage industry. In the long term, the production of large volumes of high and medium-value marine fish for world markets is likely to provide the greatest potential for sea-cage culture in Iran IR. This will be attained through investments by large companies or by vertical integration by companies contracting smaller producers, as is happening within the salmon industry in some countries today. Sea-cage culture can develop into a major industry in Iran IR, perhaps second only to the oil and gas industry.

The Iranian government has decided to establish four pilot farms during the fourth National Five Year Development Plan. At present, the first sea-cage farm with a capacity of 180 tonnes is installed between Queshm and Hengam islands in the Persian Gulf. This project will be carried out for a three year period of pilot-scale production of selected species.

HUMAN RESOURCES

The total employment from fisheries was estimated in 1994 as 97 381, with aquaculture and related activities providing employment for 10 921 (11.2 percent of total fisheries employment). In 2003 employment from fisheries, and from aquaculture and related activities reached 156 470 and 17 095 jobs, respectively (Shilat, 2003) (Table 5).

TABLE 5
Employment in aquaculture and related activities (Source: Shilat, 2003)

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Aquaculture	10 921	11 004	11 630	10 250	16 661	19 872	23 581	20 150	20 240	17 095
Total	97 381	11 848	108 398	112 181	122 170	122 961	143 148	144 398	144 584	156 470

Shrimp culture has an important role to play in poverty alleviation and creating job opportunities along the southern coasts of the country. It has already created over 4 000 direct, full-time jobs in farms and hatcheries and an equal number of indirect full-time job opportunities in feed mill plants, processing units and other activities. Part-time employment generated in related sectors (construction, transport, equipment services, etc.) is also important.

MARKET

The Islamic Republic of Iran currently exports several fish products, the most important one, of course, being Iranian caviar, which is recognized as the best in the world. Farmed shrimps are European Community-approved and also exported. In addition, canned tuna, kilka (*Clupeonella* spp.) (Thai/Japanese market) and some by-products from sturgeon caviar production (fish meat, swimbladder, gel-products from skin) are also exported.

The Islamic Republic of Iran is one of the main food producers in the region, and export to all Arabic countries is possible. With the adoption of high standards such as ISO 14000, the potential for export to the rest of the world is also very high. The export of cultured species that do not fit the Iranian eating customs, such as eel, shellfish, etc. also has a huge potential.

Fish consumption per capita in the Islamic Republic of Iran is estimated based on the total fish supply and has increased from 4.5 kg in 1998 to 6.1 kg in 2003. Increased fish supply to the community has great significance for the government as a key issue in the development of the fisheries sector.

Based on the 4th NFDP, fisheries production will exceed 760 000 tonnes, including 280 000 tonnes of freshwater fishes that do not penetrate the international market. So the producers have to rely on the domestic market. Iranians eat some 23.1 kg of beef and lamb and 11.8 kg of poultry each year. The government has been actively promoting changes in Iranian food consumption habits towards fisheries products, such as through fish-cooking training courses for housewives, fisheries products shows and direct selling around the country, release of booklets and books for children and entertainment and documentary programmes.

Marine fish and shrimp have a good demand in international markets. In 2003 the Islamic Republic of Iran exported some 20 647 tonnes of fisheries products, including caviar, marine shrimp and fish, and value-added products such as canned tuna and smoked fish, with a value of US$87.4 million. Caviar has the highest value, while shrimp has the highest contribution by volume. Considering the huge potential for shrimp culture in southern Islamic Republic of Iran, it is estimated that shrimp production will increase to 46 000 tonnes in 2009, which will need further development of international markets (Shakouri and Safiyary, 2004).

Fisheries imports are mainly tuna and fishmeal. According to the Iranian customs authority, fishery import in 2003 was estimated as 69 000 tonnes with a value of US$60 million.

APPLIED RESEARCH, EDUCATION AND TRAINING

Applied research

Several institutes and organizations have responsibility for applied research. The Iranian Fisheries Research and Training Organization (www.ifro.org) affiliated to Shilat is the major source of applied research and training on fisheries and aquaculture. It has ten research centres and two training centres in the country as follows:

- four centres located by the Persian Gulf and Oman Sea (Khuzestan, Bushehr, Hormozgan and Sistan-Baluchestan provinces);
- five fisheries research centres located by the Caspian Sea (Giulan, Mazandaran and Golestan provinces);
- the International Institute of Cold Water in Mazandaran and the International Institute of Sturgeon in Giulan; and
- the Artemia Research Center, located by Urmia Lake (works on *Artemia* and live feed).

The Supreme Committee of Research is the highest reference group and is responsible for approving fisheries research projects. University professors, representatives of executive departments of Shilat, and some experienced researchers and other experts are members of the committee.

Results of the research are submitted to Shilat as a basis for pilot projects and modification. They are then transmitted to farmers through short training courses and manuals. Shilat's training and demonstration centres play a significant role in this process. It should be mentioned that since 2005, all research departments affiliated to the Ministry are organized into one department, the Deputy of Research, Training and Extension.

Universities have a huge capacity for research activities. However, there is no effective link between industry and university. According to law, 1 percent of the total income derived from industrial activity should be invested in research and development (R&D). Agriculture is not included in this category. When there is support from IFRO and/or Shilat, interesting and valuable applied research has been made by university students and lecturers.

The Scientific and Industrial Research Organization is another agency involved in fisheries research. Researchers can submit proposals to the organization, and an accepted proposal can benefit from financial support. The organization's priority is basic and long-term research such as improving broodstock selection and breeding programmes for existing aquaculture species. The organization is expanding cooperation with other international organizations to exchange a wide range of experiences, especially on implementation of breeding programmes for fish and shrimp.

Training programmes are needed for mariculture to develop the skilled people needed for pilot projects and commercial farms. As aquaculture technology is developing rapidly, there must be a continuous process of learning new techniques. For Iran IR to be able to develop further and establish its own self-sustaining aquaculture businesses, resources should be put into a mariculture R&D centree.

Education and training

Since the 1970s, the Ministry of Science, Research and Technology has put a fisheries science course in the programme of Iranian universities. At present, some eight state and 12 open universities offer BSc courses and four state and two open universities offer MSc and PhD courses in various fields of fisheries and aquaculture science. Tehran and Chamran (Khuzestan) and Gorgan (Golestan Province) universities are the oldest of Iran's universities.

In addition the University of Applied Sciences offers fisheries training courses in two faculties located by the Caspian Sea (Rasht) and the Persian Gulf (Bushehr). The university gives priority to practical topics, aiming to meet the human resource needs of industrial aquaculture/fisheries units.

Training and Extension Services centres affiliated to Shilat are other sources for training of skilled manpower. These centres implement several short-term training courses in various fields and at various levels for both illiterate and literate farmers, as well as the educated.

TRENDS, ISSUES AND DEVELOPMENT

The third National Five Years Development Plan targeted a production of 230 000 tonnes for the aquaculture subsector, but the output in 2002 was only 76 816 tonnes (Figure 2). Besides the optimistic planning, factors affecting the low performance relative to target include:

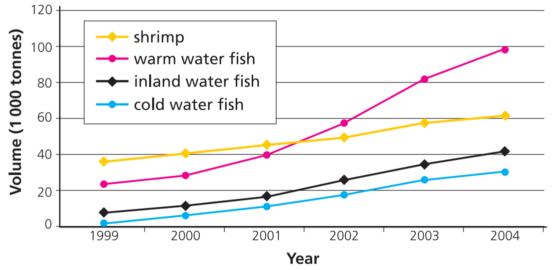
- The occurrence of dry years and low precipitation in the country. For example, compared to 1998, the total area of inland water bodies had decreased by 25 percent in 2001.
- Technology and productivity are inadequate. Compared to some other countries, the productivity derived from inputs is lower than average. For instance, the average production of carp is minimal. The main reasons for low productivity are lack of current knowledge and equipment. The efficiency of short-term training courses is reasonable, but they cannot meet the requirements of industry.

- Improvement is needed in the quantity and quality of applied research and postgraduate courses are required in all aspects of aquaculture, including farming systems, management, feed production, etc.

More investment is needed in the sector, and international and regional collaboration can assist in building skills and sharing experiences to improve the sustainability of the industry.

Establishment of fish-farm complexes is one of the Iranian government's major plans for increasing fish production. Azadegan (12 040 ha in Khuzestan Province) and Ghasreshirin (3 000 ha in Kermanshah Province) are examples where projects are ready for operation.

Figure 2
Projection for aquaculture in the 3rd National Five Years Development Plan



There are more than 40 000 rivers, springs and wells in the Islamic Republic of Iran. Some 379 of them have a capacity of more than 500 litres/sec and are located in mountainous and cold areas that offer good potential for trout farming. Studies have also indicated a huge potential for shrimp culture in the southern and northern parts of the country. Since 1992 some 45 000 ha of land in four provinces neighbouring the Persian Gulf and Oman Sea and Golestan (in the north) have been allocated to investors. Out of this, some 20 000 ha is under construction and 6 000 ha is ready for operation.

Shilat, in line with local governments countrywide, developed its 4th Five-Year Plan for Fisheries for 2005–2010 (Table 6). This plan gives attention to:

- food security through increased domestic fish production;
- quality improvement and waste reduction in fisheries;
- fish export promotion;
- market improvement;
- fish conservation and enhancement;
- deep-sea fisheries development;
- improved aquaculture productivity;
- sea-cage culture development;
- expansion of applied research; and
- increased fish consumption.

TABLE 6
Aquaculture production projections (tonnes) in the 4th Five-Year Plan for Fisheries, 2005–2009 (Source: Shilat, 2004)

	2003	2005	2006	2007	2008	2009
Shrimp farming	7 492	14 110	23 800	32 300	40 500	47 200
Coldwater fish farming	23 138	35 000	40 000	46 000	51 000	59 000
Warmwater fish farming	79 545	106 527	129 158	153 806	173 314	208 206
Sea-cage culture	0	180	800	1 500	2 900	4 400
Total	110 175	155 817	193 558	233 606	267 714	318 806

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Japan

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SUMMARY

Japan gives a high priority to food security. Fisheries demand in Japan is stable, but with decreases in Japanese fisheries production, the country has increasingly relied on imports over the past 30 years. Imported fisheries products made up 57 percent of total fisheries products in 2003.

Mariculture production makes up about 20 percent in quantity of total fisheries production. The gross value of mariculture production amounts to around US$3.8 billion. The significance of mariculture in Japan is increasing. Major mariculture species are seaweed (laver), yellowtail, red seabream, Japanese oyster, greater amberjack, common scallop and others. Recent target species are bluefin tuna, barfin flounder and grouper. In seaweed farming, *mozuku* is a remarkable species with a high content of fucoidan. The tendency for newly targeted species reflects both the expensive tastes and the health interests of consumers. Production of fisheries products for human health is particularly expected to increase in the future.

The present and future priorities for mariculture development and research in Japan are the following:

- development and refinement of aquatic animal breeding techniques;
- development of efficient feeding methods and artificial food;
- prevention of fish disease;
- polyculture systems (including integrated culture);
- utilization of deep-sea water;
- promotion of aquaculture without artificial food; and
- closed recirculation aquaculture systems.

Lately, there are also some problems with mariculture, of which the most serious is self-pollution by net cages. Some reports suggest mariculture net cages contribute up to 70 percent of the total nitrogen discharged into Japanese coastal waters. One report estimates that the level of pollution by mariculture in Japan is equivalent to 5–10 million people. Such findings clearly show that environmental pollution by mariculture has reached serious proportions in Japan and management should be carried out quickly.

From the viewpoint of protection of the coastal environment, closed recirculation systems have been highlighted as potential rearing technologies. Complete system

control would lead to environmental benefits as well as potential cost savings, increased survival rates and better biosecurity. This system is considered the future aquaculture system in Japan.

Closed recirculation systems developed by the Fisheries Research Agency (FRA) consist of a foam separation system, a biofiltration system and a sterilization system. The main characteristics of this system are improved environmental protection because of limited discharges, a high nitrification ability and space-saving, high productivity via high-density rearing and maintenance of water quality. Trials of closed recirculation aquaculture systems have just started in Japan. In some trials by a private company, fish farmed in closed recirculation systems were evaluated as high value because of their traceability and food safety.

Japanese fisheries production comes from three sources: capture fisheries, aquaculture and stock enhancement. The aim of stock enhancement is recovery and increase in fish stocks by release of artificially produced seedlings. The system of stock enhancement consists of selecting target species, managing broodstock, securing eggs and larvae and producing seed in public hatcheries, and releasing seedlings into natural waters. After release, the hatchery-produced seedlings mix with wild juveniles and a comprehensive stock management programme is operated for the fishery that includes both stocked and wild fish. Knowledge of the ecological characteristics of the target species is necessary, and it has emerged that the ecological fitness of stocked and wild fish is a key factor in stocking effectiveness. In some species (e.g. chum salmon and common scallop), stock enhancement has been shown to be highly effective, as clearly reflected by increased fishery production. However, although these stocking measures have been successful, mariculture production will be necessary for future food production. New technologies such as recirculation systems will be essential to farm fish and other aquatic products without environmental impacts.

SUPPLY AND DEMAND OF FISHERY PRODUCTS IN JAPAN

Domestic fishery production (fishery and aquaculture production)

In 2003, Japan saw its fishery and aquaculture production increase 3 percent in volume from the previous year to 6.08 million tonnes (Table 1) and shrink 8 percent in value to ¥ 1.6 trillion.

TABLE 1
Fishery and aquaculture production volume (1 000 tonnes) (Source: Annual statistics of fishery and aquaculture production. Ministry of Agriculture, Forestry and Fisheries, Japan)[1]

	1993	1998	2002	2003	Percentage change 2003/2002
Marine fishery	726	531	443	472	6
Far seas fishery	114	81	69	60	12
Offshore fishery	426	292	226	254	13
Coastal fisheries	186	158	149	158	6
Marine aquaculture	127	123	133	125	6
Inland water fisheries and aquaculture[2]	18	14	11	11	3
Total	871	668	588	608	3

[1] Due to fractional rounding, component figures may not add up to the exact totals shown.

[2] Inland-water fishery and aquaculture production in and after 2002 covers catch amount at 148 major rivers and 28 lakes and amount of production of cultured trout, ayu (sweetfish), carp and eel.

Fishery product trade

Japan's fishery product imports in 2003 declined both in volume (weight of products upon customs clearance, hereinafter the same) and value. In volume terms, the year's imports declined by 496 000 tonnes or 13 percent from the previous year to 3.325 million tonnes. In value, they dropped by ¥ 193 billion or 11 percent to ¥ 1 569.2 billion.

However, Japan remains the world's largest fishery product importer both in volume and value, accounting for 14 percent of the world's total fishery product import volume and 22 percent of total import value (as of 2002). The People's Republic of China has been the largest fishery product exporter to Japan since 1998. However, in 2003 such imports from China decreased by 120 000 tonnes or 16 percent in volume terms from the previous year and by ¥ 22.9 billion or 7 percent in value terms.

On the other hand, Japan's fishery product exports in 2003 increased by 63 000 tonnes or 21 percent to 370 000 tonnes in volume terms from the previous year, while decreasing by ¥ 1.1 billion or 1 percent to ¥ 135.4 billion in value. The above figures on volume and value for 2003 were calculated on the basis of 2002 statistics (Table 2).

TABLE 2
World fishery product trade: five largest exporters and importers in value (US$ million) and volume (10 000 tonnes) in 2002 (Source: FAO Fishstats – Fisheries Commodities Production and Trade, 1976–2002, FAO)

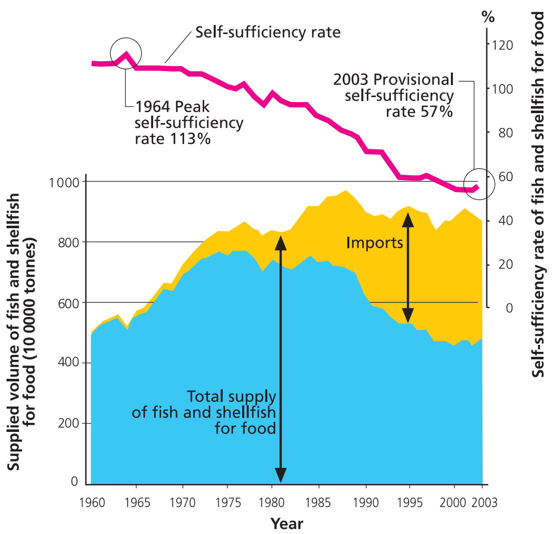
Import		**World total**	**Japan**	**USA**	**Spain**	**France**	**Italy**	**-**
	Value	62 318	13 863	10 150	3 867	3 237	2 917	-
	% Share	100	22	16	6	5	5	-
		World total	**Japan**	**China**	**USA**	**Spain**	**Denmark**	**-**
	Volume	2 774	382	248	207	146	140	-
		100	14	9	7	5	5	-
Export		**World total**	**China**	**Thailand**	**Norway**	**USA**	**Canada**	**Japan (23rd)**
	Value	58 500	4 601	3 692	3 601	3 319	3 052	818
	% Share	100	8	6	6	6	5	1
		World total	**Norway**	**China**	**Peru**	**USA**	**Denmark**	**Japan (28th)**
	Volume	2 742	210	206	186	136	127	31
	% Share	100	8	8	7	5	5	1

Consumption of fishery products and self-sufficiency rate

In 2003 the fish and shellfish (on an original weight basis) supplied for domestic consumption decreased 2 percent to 10.98 million tonnes from the previous year, of which about 80 percent was supplied for human consumption, down 2 percent to 8.39 million tonnes. Per capita annual fishery product consumption came to 65.7 kg on a crude food weight basis and to 36.2 kg on a net weight basis.

The "self-sufficiency" rate of fish and shellfish for food consumption in 2003 rose by 4 percentage points to 57 percent as domestic production increased and imports decreased (Figure 1).

Figure 1
Changes in self-sufficiency rate of fish and shellfish for human food
(Source: Food Balance Sheets, MAFF, Japan)



MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Status of farming of selected species

Target species and their production

In Japan, farming of oyster and laver has been prosperously practiced since the early seventeenth century. The gross of mariculture production amounted to ¥ 435.6 billion in 2004 (MAFF, 2005a). Fish, seaweed, shellfish, pearl, prawn and the others showed 196.5, 118.5, 72.5, 19.9, 8 and ¥ 20.2 billion, respectively (Table 3). The major mariculture species are as follows: fish – yellowtail, greater amberjack, red seabream, coho salmon, torafugu, Bastard halibut and white trevally; crustaceans – kuruma prawn; shellfish – common scallop, Japanese oyster and Japanese pearl oyster; and seaweed – laver, *konbu* tangle and *wakame*. The top five mariculture species in terms of production value were, in order of value: yellowtail and amberjack, laver, red seabream, common scallop and Japanese oyster. These species are very popular in Japan and important as the food for Japanese traditional cooking.

TABLE 3
Major mariculture species and production in Japan (Source: MAFF, 2005a)

Target species		Annual production in 2004	
Common name	**Scientific name**	**Value (¥ billion)**	**Volume (1 000 tonnes)**
Yellowtail	*Seriola quinqueradiata*	72.87	100
Greater amberjack	*Seriola dumerili*	36.43	50
Red seabream	*Pagrus major*	50.72	81
Torafugu	*Takifugu rubripes*	10.82	4
Bastard halibut	*Paralichthys olivaceus*	7.71	5
White trevally	*Pseudoaranx dentax*	4.27	3
Coho salmon	*Oncorhynchus kisutch*	3.57	10
Japanese jack mackerel	*Trachurus japonicus*	1.85	3
Other fish	-	8.24	7
Subtotal in fish	-	196.46	261
Pacific oyster	*Crassostrea gigas*	36.78	236
Common scallop	*Patinopecten yessoensis*	33.99	215
Other shellfish	-	1.69	2
Subtotal in shellfish	-	72.46	453
Kuruma prawn	*Penaeus japonicus*	8.04	2
Sea-squirt	*Halocynthia roretzi*	0.96	16
Other aquatic fauna	-	0.47	0
Nori	*Porphyra* sp.[1]	97.91	359
Wakame	*Undaria pinnatifida*	9.70	62
Konbu	*Laminaria* sp.[1]	8.49	47
Mozuku	*Nemacystus* sp.[1]	2.03	16
Other seaweed	-	0.36	0
Subtotal in seaweed	-	118.48	484
Pearl	*Pinctada fucata*[2]	19.85	31
Seed for aquaculture	-	18.84	– –
Total		435.55	1 216

[1] Representative species.
[2] Mother shell.

Remarkable species

One of the most remarkable species in Japan is bluefin tuna, *Thunnus thynnus* (MAFF, 2005b), because of:

- its high demand and high market value;
- the depletion of wild stocks and tighter regulation for pelagic fisheries;
- the technical development for production of high-quality fish; and
- the production of artificial seed through research progress.

Barfin flounder, *Verasper moseri*, is another important species whose culture is growing rapidly. It grows to a large size with a high commercial value (Andoh, Watanabe and Matsubara, 1999). Aquaculture of barfin flounder has been expanding in the cold waters of northern Japan, especially in Hokkaido and Iwate Prefecture. Aquaculture of grouper, *Epinephelus* sp., has been practised in the western part of Japan; however, the culture of this species is not so successful because of its vulnerability to viral nervous necrosis (VNN) (Furuta, 1996).

Among seaweeds, *mozuku* (*Nemacystus* sp.) and Okinawa *mozuku* (*Cladosiphon okamuranus*) are remarkable species with a high content of fucoidan, a kind of glycan (Noda, 1994). It has been reported that fucoidan is an effective substance for enhancing human immune response, and production of Okinawa *mozuku* is rapidly increasing in Okinawa Prefecture due to trends towards consuming healthy foods.

The establishment of aquaculture species in the country is influenced by the consumer's lucrative taste preference and a market trend towards consuming healthy products. The demand for commodities that are consumed directly, such as *mozuku*, or that are used as ingredients in health supplement products especially seem likely to increase in the future.

PRIORITIES FOR DEVELOPMENT AND RESEARCH

Present and future priorities for research and development of mariculture in Japan are presented below.

Development of breeding techniques

The application of molecular biological methods to aquaculture is an important subject, especially to develop improved breeds having high growth and strong tolerance to disease. In Japan, selective breeding has been practiced in goldfish and carp for a long time. Recently many trials of breeding technology (e.g. hybridization; production of diploids, triploids and clones) have been conducted in Japan for parrotfish, red seabream, bastard halibut, laver, Japanese oyster, etc. (Taniguchi and Aoki, 1994). Rapidly advancing new genetic research, especially marker-aided selection by microsatellite DNA markers, is leading to a new level of possibilities in breeding technologies.

Development of efficient feeding methods and artificial feeds

Self-pollution by mariculture is causing serious damage to the coastal environment in Japan. Therefore, development of artificial feeds for higher food conversion efficiency and introduction of on-demand fish feeding systems are necessary for environmental conservation. An on-demand feeding system is an effective management method for reduction of waste feed, and trials have been undertaken for some marine fish such as red seabream, yellowtail, grouper, torafugu and rainbow trout (Kohbara *et al*., 2000).

Disease prevention

It is reported that the annual loss of Japanese aquaculture production due to fish disease amounts to ¥ 15–25 billion (3–6 percent of total production). Therefore, development of preventive measures against disease is a matter of great urgency. Several viral diseases [e.g. yellowtail ascites virus (YAV), hirame rhabdovirus (HRV), baculoviral mid-gut gland necrosis virus (BMN), and viral hemorrhagic septisemia (VHS)] have caused increasing problems of mass mortality in seed production and grow out. Much research has been conducted on methods for detection of virus, specific viral characteristics, sources of infection, interception of infection routes, development of effective and safe vaccines, and reinforcement of fish immunity by special diets and control of environmental conditions (Muroga, 1994).

Polyculture system

Effective utilization of space and resources to increase productivity is an important subject in Japan. The fundamental concept of the polyculture system is "zero emission" by combining species with different feeding behaviours and ecological patterns, but not those negatively interacting with each other. Some case studies on fish, seaweed, sea cucumber and abalone show positive results with increased productivity.

Utilization of deep-sea water

Utilization of deep-sea water for aquaculture has been studied and tested in recent years, for example in Kochi Prefecture, where deep-sea water is pumped up from a depth below 300 m. Characteristics of deep-sea water are:

- its stable low temperature, typically below 10 °C;
- its purity, especially its low concentration of marine bacteria; and
- its richness in nutrients such as nitrogen, phosphoric acid and silicate.

Technology for the aquaculture of bastard halibut and other deep-sea species can be successfully developed using this water, because it can provide a good environment for cultivation of phytoplankton, kelp and other seaweeds and also contains very few pathogenic bacteria that may cause disease.

Promotion of low-trophic commodities

Aquaculture of shellfish and seaweed is practiced without supplementary feeding. Shellfish grow by consuming phytoplankton and suspended organic particles, while seaweeds grow by the uptake of nitrogen and phosphoric acid. These aquaculture commodities give some benefit to the coastal environment – for example, by direct removal of excess nutrients and suspended organic matter and by the indirect effect of removing nitrogen and phosphorus, leading to their removal from seawater via harvesting of products (shellfish and seaweed) (Matsuda, 2002). Therefore, aquaculture of low-trophic commodities will be promoted, especially considering the status of coastal environments in the country.

Identification of better management practices (BMPs) for existing farmed species and systems to mitigate environmental impacts

Problems of existing mariculture

The self-sufficiency rate, a serious concern in Japan, has decreased considerably in recent years due to decreased domestic supply and increased imports. The self-sufficiency rate in fish and shellfish was reduced by half over the past 30 years, down to 57 percent in 2003 (MAFF, 2005b) (Figure 1). Therefore promotion of aquaculture is important to recover the self-sufficiency rate. However, there are issues to be considered for promotion of mariculture in Japan. Drug residues and environmental pollution in aquaculture areas have led to a negative image for aquaculture among consumers and possibly restrained the consumption of aquaculture products. Environmental pollution, in particular, is a serious problem due to wasted feed, urine, fish faeces and other waste products that are discharged into coastal waters by intensive mariculture operations (Figure 2). The level of mariculture-caused pollution compared to a daily discharge of nitrogen and phosphorus from humans (Maruyama and Suzuki, 1998;, Maruyama, 1999) suggests that pollution from Japanese mariculture is equal to the waste produced by 5–7 million people in terms of nitrogen and 9–10 million people in terms of phosphorus (Maruyama, 1999) (Table 4). These results clearly show that environmental pollution by mariculture has reached a serious condition and needs improved management.

Figure 2
Nitrogen balance in marine rainbow trout cage farming
(Source: modified from Hal *et al.*, 1992)

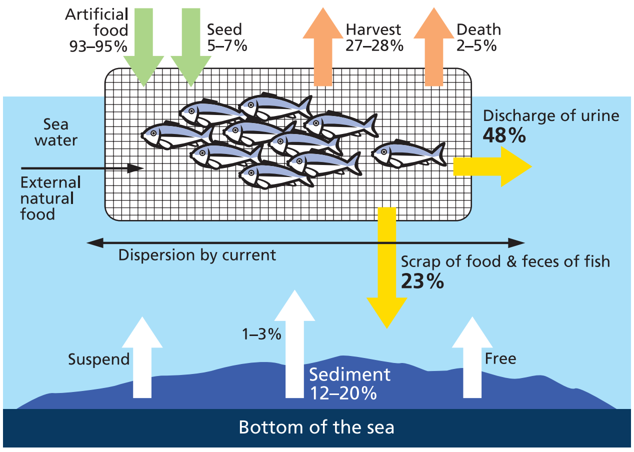


TABLE 4
Trial calculation of the coastal pollution level from aquaculture as compared to that from human population (Source: Maruyama, 1999)[1]

Origin for estimation	Production (1 000 tonnes)	Estimated human population (million)	
		Total nitrogen (TN)	Total phosphorus (TP)
Amount of aquaculture production	325	7.5	10.0
Amount of artificial food production	500	5.4	9.6

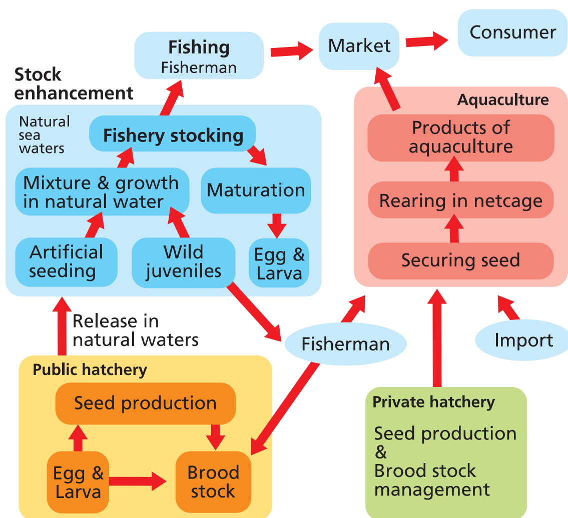
[1] Standard unit for pollution: TN: 100 kg-TN/tonnes – aquaculture production
TP: 20 kg-TP/tonnes – aquaculture production
Standard unit for exchange to people: TN: 12 g-TN/person/day
TP: 1.8 g-TP/person/day

Stock enhancement in harmony with the environment

In Japan, stock enhancement (sea farming) has been practiced in harmony with the environment as a key measure in preserving and enhancing fisheries stocks (Figure 3). The National Center for Stock Enhancement (NCSE) in the Fisheries Research Agency (FRA) started the technical development of stock enhancement in 1963 by releasing artificial seed (juveniles) in a project to actively recover the decreasing fishery stock (Imamura, 1999). Stock enhancement consists of:

- selection of target species;
- broodstock management;
- securing fertilized eggs;
- seed production;
- rearing in nursery and acclimation to the natural environment;
- release;
- comprehensive stock management (released and natural stock); and
- monitoring of stock and evaluating the share of stocked fish in fishery production.

Figure 3
The concept of stock enhancement and system of Japanese fisheries



Many marine species have been released in natural waters. In some species, such as the chum salmon (*Oncorhynchus keta*) and common scallop (*Patinopecten yessoensis*), the effects of stock enhancement are clearly reflected by an increase of fishery production (Imamura, 1999; Kitada, 2001). Recent advances in marker techniques allow better assessments of the effectiveness of stocking, and case studies have reported high return rates (8–50 percent) in red seabream, bastard halibut and abalone (Kitada, 2001).

Knowledge of the ecology of the target species is necessary to support stock enhancement, and it is important that the target species fits into the local ecological system in order to achieve effective results from stock enhancement programmes.

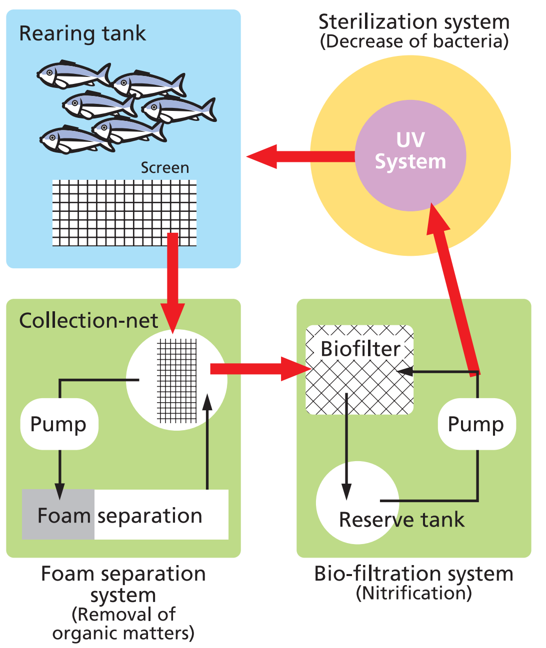
Closed recirculation systems

Considering the need to preserve coastal environments, closed recirculation systems are highlighted as a rearing technology that is a type of "zero emission" fish-rearing system. Research on closed recirculation systems started in the 1950s (Saeki, 1958). Drs Saeki and Hirayama were the pioneers of research for a closed recirculation system through developmental and fundamental research on the biofilter (Saeki, 1958;, Hirayama, 1970). Complete system control leads to many benefits, including:

- reduction of pollution;
- avoidance of external risk (e.g. disease and poor water quality);
- highly stable productivity; and
- energy savings.

Therefore, there is increasing interest in developing hardware and software for such rearing technology. A number of research studies and trials on closed recirculation systems are ongoing, such as high-density rearing of bastard halibut and eel (Kikuchi *et al.*, 1991; Honda *et al.*, 1993; Suzuki and Maruyama, 1999); however, their use by private companies and fishermen has just started. The private sector, academia and government in Japan are cooperating on this topic, and further development and implementation are anticipated.

Figure 4
Seed production in a closed recirculation system at Yashima Station



At Yashima Station, National Center for Stock Enhancement (NCSE), FRA, technical development of a closed recirculation system for seed production in red seabream started in 2000 (Tomoda, Fushimi and Kurokura, 2005). The closed recirculation system developed by this centre consisted of a foam separation unit, a biofiltration system and a ultraviolet (UV) sterilization system. These function for removal of organic matter in rearing water, nitrification and sterilization of water, respectively (Figure 4).

At present, the technical level of seed production by this system is higher than that acheivedachieved by flow-through rearing (Kamoshida, Yamazaki and Yamamoto, 2006). Using the closed recirculation system, survival and production densities from hatched larvae to juveniles of 30 mm in TL are 45–70 percent and 5 000–7 000 individuals per m^3, and those in the case of juveniles of 60 mm in TL are 50 percent and 5 000 individuals per m^3, respectively (Kamoshida, Yamazaki and

Yamamoto, 2006). The water exchange rate is below 0.5 percent per day. Therefore, we can establish the near-perfect, no discharge system for seed production. Water quality during the rearing period from hatching to juveniles of 30 mm in TL (about 50 days) was also investigated. Concentrations of ammonia nitrogen and nitrite-nitrogen in rearing water are kept below 1.0 mg/literlitre and 0.5 mg/literlitre, respectively. Therefore, under a condition of little water exchange, a closed recirculation system can be used to maintain suitable water conditions for seed production and rearing of juvenile red seabream. In the future, this closed recirculation system will be applied to other species for which seed production has proved difficult.

CONCLUSIONS

Fishery production in Japan consists of capture fisheries, aquaculture and stock enhancement (sea-farming). Relatively closed coastal waters are considered as large-scale farming grounds; and stock enhancement (sea farming) and sea ranching, intermediate between capture fisheries and aquaculture, are operating in those locations. Fisheries management in the country is comprehensive, involving stocked resources and wild resources and with rational fisheries regulations in place (e.g. limits on catch, fishing gear and fishing period). In other words, the fundamental productivity of the marine environment is being effectively enhanced for fishery production. However, the productivity of natural coastal waters is exhausted by the disappearance of tidelands, seagrass and seaweed beds (Shibagaki, 2002).

National policy aims to increase self-sufficiency in fish and shellfish products, and mariculture is an important means of achieving that goal. The switch in aquaculture systems to closed recirculation systems that preserve the environment will become an increasingly important part of future mariculture production. We consider it necessary for the government to support aquaculture companies that switch to more sustainable aquaculture production methods, such as using the closed recirculation system.

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The Republic of Korea

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INTRODUCTION

The Republic of Korea is a peninsula with a coastline of almost 9 000 km and an archipelago of some 3 000 islands. Consequently, fishing has always been a national industry of major economic importance. However, a continuous decrease in capture production in recent years has led to an increased attention to aquaculture, with an attendant increase in culture production. The total national fisheries production in 2003 was 2 492 545 tonnes, comprising capture and culture production of 1 652 700 and 839 845 tonnes, respectively. This indicates a shift towards aquaculture when compared with the capture and culture production quantities of 1 838 018 and 667 883 tonnes, respectively, in 2000. Korean aquaculture is dominated by the marine species. Marine aquaculture contributed 98 percent (826 245 tonnes) of the total aquaculture production of 839 845 tonnes in 2003.

Despite the decline in capture production, the demand for aquatic products has been on the increase. The Republic of Korea recorded a trade deficit in fishery products for the first time in 2001. To meet the demand for aquatic products, further development of the aquaculture sector is needed, especially the marine subsector, which produces most aquatic foods.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKETS

An analysis of marine aquaculture products demand, trade and markets trend, locally and nationally

Since the Republic of Korea is a peninsula, marine products are a major constituent of the food of the people. However, in recent years there has been a marked increase in consumption of marine foods in line with a general increase in consumption of aquatic products. This trend is attributed to the concern for health; consumers now prefer eating aquatic products as alternatives to red meats due to their health benefits. As a result of the improved purchasing power of consumers with concomitant improved standard of living, the demand for high-value species has also increased. There is an increased demand for high-value fish species such as Korean rockfish and olive flounder. Demand for shrimps has equally increased.

Imports and exports of fishery products by major countries and the trends of export, import and trade balance of fishery in the Republic of Korea are shown in Tables 1 and 2, respectively. Unfortunately, data on mariculture trade flows are not available, as trade figures are reported for total fishery products and not individually for the various subsectors. From the tables, it can be seen that there has been a continuous increase in trade deficits (in both quantity and value) in recent years. The Republic of Korea recorded the first trade deficit (in value) in 2001. However, with the government's policies to encourage aquaculture production and the shift towards production of high-value marine species such as Korean rockfish, olive flounder, oysters and fleshy shrimp, it is expected that the trend in balance of trade for marine aquaculture as well as total aquaculture will be reversed.

TABLE 1
Imports and exports of fishery products by major countries (tonnes and US$1 000)

	2000		2001		2002		2003	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value
Imports								
Total	749 191	1 410 598	1 056 252	1 648 372	1 186 400	1 884 417	1 238 603	1 961 145
China	283 420	486 841	474 045	634 449	491 315	719 314	461 971	713 538
Russia	81 265	125 031	92 856	153 756	189 464	215 638	269 918	299 252
USA	75 588	145 366	93 969	158 520	89 603	173 774	82 485	152 677
Japan	67 741	185 109	69 679	139 129	74 536	146 497	69 257	148 699
Viet Nam	33 374	72 240	49 107	101 486	61 504	121 733	67 416	129 878
Others	207 803	396 011	276 596	461 032	279 978	507 461	287 556	517 101
Exports								
Total	533 824	1 504 470	435 691	1 273 619	429 884	1 160 435	424 785	1 129 385
Japan	215 479	1 125 248	179 335	924 873	179 069	823 117	150 155	740 447
China	93 134	84 090	53 673	55 709	44 290	48 345	55 708	70 769
Thailand	44 805	22 691	47 256	32 943	46 295	34 492	55 304	38 354
EU	35 749	64 596	49 429	75 159	39 912	63 760	46 605	78 089
USA	29 215	78 712	27 281	82 210	25 462	77 625	22 964	80 385
Others	115 442	129 133	78 717	102 725	94 856	113 096	94 049	121 341

TABLE 2
Trends of export, import and trade balance of fishery in the Republic of Korea (US$m)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Export	1 643	1 518	1 496	1 647	1 722	1 635	1 493	1 369	1 521	1 504	1 274	1 160	1 129
Import	576	506	542	726	843	1 080	1 045	587	1 179	1 411	1 648	1 884	1 961
Trade balance	1 066	1 012	954	921	879	555	447	782	342	94	-375	-724	-832

Role of aquaculture vs. fisheries as supply

Capture and aquaculture production quantities over two decades and in the year 2003 in the Republic of Korea are summarized in Table 3. The total national production in 2003 was 2 492 545 tonnes, comprising capture and culture production of 1 652 700 and 839 845 tonnes, respectively. This indicates a shift towards aquaculture when compared with the capture and culture production quantities of 1 838 018 and 667 883 tonnes, respectively, in 2000. The increase was a result of the government's aquaculture promotion policy and fleet reduction programme. The 2003 aquaculture production figure comprises marine production of 826 245 tonnes and freshwater production of 13 600 tonnes. The total aquaculture production value was US$1.06 billion.

TABLE 3
Capture and aquaculture production in the Republic of Korea (tonnes) (Source: FAO, 2004)

	1980	1985	1990	1995	2000	2003
Marine capture	1 840 938	2 268 584	2 471 584	2 333 525	1 830 878	1 647 974
Freshwater capture	22 290	34 463	25 325	8 765	7 140	4 726
Total capture	1 863 228	2 303 047	2 496 909	2 342 290	1 838 018	1 652 700
Mariculture	544 402	787 571	772 729	996 889	654 440	826 245
Freshwater aquaculture	731	3 198	15 836	20 365	13 443	13 600
Total aquaculture	545 133	790 769	788 565	1 017 254	667 883	839 845
Grand total	2 408 361	3 093 816	3 285 474	3 359 544	2 505 901	2 492 545

Consumer trends, preferences and buying patterns

As previously mentioned, there has been an increase in demand for aquatic products, including marine foods. Similarly, the demand for high-value species among the marine products has been on the increase. This increase is due to increased purchasing power of consumers, concern for health, popular beliefs and other factors. For instance, many consumers prefer raw fish (mainly olive flounder) for its nutritional value. In the same manner, many Koreans eat Japanese eel, one of the popular species, for the purported aphrodisiac properties of the species.

Besides the preference for high-value species of fish, there has also been a trend towards selection of value-added products. To respond to the buying pattern of consumers, efforts are now made to establish a consumer-oriented cultivated marine products supply to develop the processing method to produce high value-added products.

Market chain organization, market trends and vulnerability

Distinctions are hardly made between culture and capture marine products in the analysis of marketing channels of fishery products. As most of the marine aquaculture farms are located in the coastal areas due to their reliance on natural seawater, it can be seen that marine aquaculture products basically follow the same distribution systems as the fishery products that are also available in these areas. Marketing and distribution of the products at landing ports take place through fishery cooperative auction markets and the Busan common fish markets, which are always located at water fronts, but distribution to consumption areas is made through wholesale markets, inland joint-sale and direct-sale markets and retailers. The final consumers usually get their supplies from conventional markets, supermarkets, discount stores, department stores and seafood wholesale markets.

Since marine aquaculture products basically follow the same distribution systems as the capture products, trends in marketing of capture and aquaculture products are the same. Several measures are being taken by the Korean government to ensure stable market prices for fishery products through the establishment of the "Price Stabilization Fund". The fund is intended to cover ten fishery products items, including dry seaweed, frozen squid and frozen hair-tail fish. Fishery marketing systems have been improved through the expansion of market facilities and the upgrading of the consignment system on landing sites and the distribution capacity at areas with large consumer populations. Since October 1997, the government has liberalized the consignment system at landing sites. This policy has been a part of a two-stage free market system first introduced in 1996. Five direct-sale market facilities have been established at large urban areas to strengthen the distribution and handling capacity in areas where large populations of consumers are found. The improvement includes the reduction of distribution and handling steps and marketing margins, and the promotion of direct shipping to consumers by fishermen's cooperatives.

The Republic of Korea imports aquatic products from the People's Republic of China, the Russian Federation, the United States of America, Japan and Viet Nam for domestic consumption and re-export. No difference is ever made between imported and domestically cultured products while reporting the total export quantities and values. In 2003, a total of 424 785 tonnes of fishery products valued at US$1.13 billion was exported, while the import was 1 238 603 tonnes yielding US$1.96 billion (Table 1). The Republic of Korea exports processed aquatic products to Japan, the United States of America and Europe.

LIVELIHOOD OPPORTUNITIES AND MARICULTURE

Since 1975, coastal communities have been allowed to obtain licences for aquaculture in fishery sites. Coastal communities began actively participating in finfish aquaculture in the late 1990s. At that time, finfish aquaculture was seen as a high-profit business in fisheries but personal licenses were not easily available to private farmers. In addition, fisheries agreements between the Republic of Korea, Japan and China adversely affected coastal communities. Part of the government's efforts at reviving coastal communities was approval of licences for mariculture, which led to the explosive growth of finfish aquaculture. This rapid growth caused a decrease in the market price of live fish due to over-production and importation of low-cost live fish from China. As a result, many coastal community farmers became bankrupt.

According to the Korea National Statistical Office, the number of persons employed in the aquaculture industry in 2004 was 63 570, and they constituted around 33.2 percent of the total number of fishermen employed in the fishery sector. These people are concentrated around the major production cities including Busan, Incheon, Ulsan, Kyonggi, Kangwon, Chungnam, Chonbuk, Chonnam, Kyongbuk, Kyongnam and Jeju. Three of these cities are the highest employers of labour in the aquaculture industry; they are Chonnam, Kyongnam and Chungnam, in that order. Mariculture makes the highest contribution to employment of labour. About 92 percent of the people employed in the aquaculture industry in 2004 were involved in mariculture, while only 8 percent were involved in freshwater aquaculture. Of those employed in marine aquaculture, 49.7 percent were engaged in production of molluscs. Seaweed, finfish and crustacean production contributed 29.1, 9.05 and 0.3 percent, respectively. About 1.5 percent of the people were employed in hatcheries. Apart from people directly involved in aquaculture, many others are engaged in subsidiary industries, including feed manufacturing, product processing, transportation, sales and export, and research and development.

Currently there are 1 951 coastal communities around the country, and the annual income per household is US$21 200, less than that of stockbreeders and farm workers (US$50 000 and US$35 000, respectively). It is necessary that actions be taken to improve the income of communities engaged in aquaculture. Loans and grants should be made available to the farmers. Low-cost, high-efficiency and low-pollution feeds should be developed. Programmes to increase the competitiveness of culturing strategic species should be established. Fallowing years for farming sites should be established, and formulated feeds should be subsidized to discourage farmers from using raw fish-based feeds.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Training centres of excellence

Eighteen fisheries subsidiary organizations, including several branch offices of the Ministry of Maritime Affairs and Fisheries (MOMAF) exist in rural areas, mostly located along the coastal areas. The role of these organizations is to support fishermen with information, training and government funding. The major government aquaculture research institutes are the National Fisheries Research Development Institute (NFRDI) and Pukyong National University.

Existing mechanisms for technology transfer and mechanisms for effective dissemination of R&D to farmers and other stakeholders

For workers in the industry to remain relevant in this information age, 13 890 people were trained in 2004. In the future, intermediate and higher-level courses will be held to educate fisherman thoroughly. Computers, connected to the Internet, together with printers and other accessories were installed in the homes of fish farmers in 100 model fishing villages. The information-sharing systems constructed in 31 different locations (MOMAF, NFRDI and local governmental agencies) allow fisherman to have remote access to essential information about fisheries. Fishermen can communicate effectively through a specialized homepage (www.badaro21.net).

Books providing culture standards for each aquaculture species have been published by NFRDI. Furthermore, the Fisheries Outlook Review, providing general information on the status, prospects, monthly market prices, production, exports and imports of Japanese flounder and laver, is published by the Korea Maritime Institute and Fisheries Outlook Center.

Present training activities and likely future requirements

In 2004, Wando Maritime and Fisheries Office, one of the branch offices of Mokpo Regional Maritime Affairs and Fisheries Office, organized a seminar, inviting the chief executive officer (CEO) of SAMYANG Co., Ltd. as the guest speaker to enlighten seaweed farmers and train them on how to collect seeds of laver under indoor culture conditions.

Buan Fisheries Technology Institute, one of the branch offices of Gunsan Regional Maritime Affairs and Fisheries Office, established test farms for clam (*Meretrix lusoria*) aquaculture in four locations around the Buan area. Education of local aquaculture farmers on optimal management systems, activation and resource enhancement of clam and the development of locally specialized products for the Buan area was carried out from 2003 to 2004.

Pohang Regional Maritime Affairs and Fisheries office carried out two projects with local aquaculture farmers. One of the projects was the polyculture of Japanese flounder and abalone in land-based tanks. A continuous decrease in market price of flounder, a high-value species, led to the search for a new technique to produce high-value-added species. An experiment for the production of flounder and abalone, another high-value species, in a polyculture system was carried out by the office and the local aquaculture farmers in a test farm. Results showed the possibility of making profits with polyculture. Another project was the establishment of a new aquaculture farm for the production of sea squirt (*Halocynthia roretzi*) in 22–30 m deep sea. Saturation of sea squirt farms in 10–20 m deep sea area had resulted in low productivity; however, high productivity was recorded following the establishment of new farms in the deeper water.

Programmes to raise work efficiency for mariculture are carried out with other parts of fisheries by the governmental agencies and national institutes.

Due to the industrialization and development of the service industry, most youths are not interested in the fisheries industry; they prefer to find white-collar jobs in urban areas, leading to a reduction in workforce in the fisheries sector. This calls for measures to attract the population to the fisheries sector in order to increase the sector's productivity. Governmental agencies introduced programmes to provide support to students to meet their educational needs and to help them become established in the aquaculture industry. From 1981 to 2004, a total of US$360 million was disbursed and 16 029 people were supported and specially trained by local governmental agencies and the Division of Human Resources Development, NFRDI.

As part of measures to reduce the deficiency of work force in the fisheries industry, US$95 000 was distributed to four of the fisheries high schools by the governmental agencies to support entrance and tuition fees in 2004.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Status of farming of selected species

Total mariculture production by major product groups in the Republic of Korea over two decades and in the year 2003 is shown in Table 4. Seaweed has always topped the total mariculture production followed by molluscs and finfish, in that order, while crustaceans are the least important group in terms of production quantity. Seaweed contributed 55 percent (452 054 tonnes) of the total mariculture production of 826 245 tonnes in 2003. Of interest, however, is the sharp increase in finfish and crustacean production in this millennium.

Table 5 shows the seaweed mariculture production by species in the Republic of Korea in 2003. Sea mustard and laver made up 44 percent and 43 percent, respectively, of the total seaweed production of 452 054 tonnes in 2003. Other species cultured include fusiforme and kelp. These species are cultured using fixed and semi-floating culture systems.

Mollusc production is dominated by oysters, which made up 79 percent (238 326 tonnes) of the total production of 301 540 tonnes in 2003 (Table 6). Oysters are cultured mostly in the south coast of the country by the long-line hanging culture technique. Other species of mollusc cultured in the Republic of Korea are short neck, sea mussel, ark shell, scallop, pen shell, cockles, venus clam, abalones and hard clam.

Marine finfish culture is a major subsector of the mariculture and overall aquaculture industry in the Republic of Korea, although the contribution by this subsector in terms of quantity is relatively low. Furthermore, it is encouraging that the subsector has experienced a sharp growth in recent years in terms of total quantity and value, with the production topped by two high-value species, olive flounder and Korean rockfish, as shown in Table 7. Olive flounder is cultured in onshore tank farms, while rockfish is farmed in offshore floating net-pens.

Although the Republic of Korea produces a number of crustaceans, only the fleshy shrimp was cultured in 2003 to a significant quantity, as reported by the Fisheries Association of Korea (Table 8). Fleshy shrimp is cultured in ponds, mostly along the west coast of the peninsula.

TABLE 4
Total mariculture production in the Republic of Korea (tonnes) (Source: FAO, 2004)

Group	1980	1985	1990	1995	2000	2003
Finfish	4 468	20 988	34 958	35 100	56 217	80 804
Crustaceans	86	87	312	438	1 158	2 324
Molluscs	281 587	369 035	325 590	312 252	222 609	291 063
Seaweeds	258 261	397 461	411 869	649 099	374 456	452 054
Total	544 402	787 571	772 729	996 889	654 440	826 245

TABLE 5
Seaweed mariculture production by species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Sea mustard	198 172
Laver	193 553
Fusiforme	33 661
Kelp	25 259
Others	1 363
Total	452 054

TABLE 6
Mollusc mariculture production by species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Oysters	238 326
Short neck	27 494
Hard clam	15 785
Sea mussel	13 653
Cockles	3 842
Ark shell	2 440
Others	-
Total	301 540

TABLE 7
Finfish mariculture production and species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Flounder	34 533
Rockfish	23 771
Common seabass	2 778
Yellowtail	114
Mullet	4 093
Red seabream	4 417
Others	
Black porgy (*Acanthopaagrus schlegeli*)	1 084
Parrot fish (*Oplegnathus fasciatus*)	-
Puffer (*Takifugu obscurus*)	14
Fill fish (*Monacanthus* sp.)	-
Convict grouper (*Epinephelus septemfasciatus*)	39
Okhostk atka mackerel (*Peurogrammus azonus*)	-
Total	70 843

TABLE 8
Crustacean mariculture production and species in 2003 (Source: The Fisheries Association of Korea, 2004)

Species	Quantity (tonnes)
Fleshy shrimp *(Penaeus chinensis)*	2 324
Kuruma prawn *(Penaeus japonicus)*	0
Others	
Chinese mitten crab (*Eriocheir sinensis*)	-
Mitten crab (*Eriocheir japonicus*)	-
Blue crab (*Portunus trituberculatus*)	-
Snow crab (*Chionoecetes opilio*)	-
Total	2 324

PRIORITIES FOR DEVELOPMENT AND RESEARCH

Due to the dwindling capture production, efforts are made to encourage aquaculture production, and there have been positive results, with mariculture as the leading subsector, as indicated in Table 3. However, Korean mariculture still faces some problems, and it is necessary that these be solved so that the subsector can grow to meet the ever-increasing demand for marine products.

One important issue is the imbalance between the level of production and the prioritization of research for the different cultured species. There are wide disparities in output of the same species between the different locations, and these need to be explained and resolved.

Cultivation of some species still relies on the collection of wild larvae and supplies can barely meet the demand. This practice, in turn, has a negative impact on the prevention and treatment of the common diseases such as lymphocystis, *Edwardsiella* and *Vibrio* in fish culture, *Marteilioides chungmuensis* in oyster culture, and viral diseases in shrimp culture. There is the need to improve seed production technology, establish disease control centers, develop cheap and highly efficient vaccines, develop natural immunostimulants, improve culture facilities and introduce species with short production cycles and high productivity. There are also problems in the manufacture and improvement of feeds, and there is a great need for effective environmental protection and monitoring systems.

Identification of better management practices for existing farmed species and systems to mitigate environmental impacts

Regrettably, although marine aquaculture in the Republic of Korea has recorded a huge increase in recent years, there has been a marked decline in the quality of the products due to the deteriorating environmental conditions of aquaculture farms. Initiatives have been taken by the government to address this issue of deteriorating product quality through the introduction of new coastal mariculture maintenance programmes consisting of three components: general mariculture ground maintenance, special mariculture ground maintenance and demonstration mariculture ground maintenance. The benefits of the coastal mariculture maintenance programmes were clearly demonstrated by the regeneration of aquatic micro-organisms and increased production per unit area, as well as improved quality of products.

On 29 January 2000, the Farming Ground Management Act was enacted to build a sustainable fishery and to improve the productivity of farm sites. The act introduced a system of recess years for the mariculture sites to increase their productivity. The act also introduced the inspection and standardization of environment of farm sites.

The Fishery Promotion Act, which was enacted on 14 January 2002, enables the government to establish a framework to promote aquaculture every five years. One of the functions of the act is to control and manage a fish health programme that can help aquaculture farmers to control diseases. However, much still has to be done to educate the farmers on the early diagnosis and prevention of diseases.

Currently, efforts are being made to further develop offshore aquaculture technology in the Republic of Korea. Other technologies and techniques need to be introduced and the existing ones improved. The optimal stocking densities for the existing species and systems should be established, and farmers should be encouraged to adopt polyculture where necessary and applicable. At present most Korean farmers use formulated feeds, but farmers need to be encouraged to maintain this practice, stressing the negative impacts of the use of raw fish on the environment. High-energy-density feeds with high digestibility should be formulated and used to reduce the nutrient load in effluents.

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Malaysia

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INTRODUCTION

Malaysia is located in the heart of Southeast Asia. Consisting of 330 200 km^2, the country is divided into two main regions: Peninsular Malaysia, which lies south of Thailand, and East Malaysia, which can be found north of Indonesia on the Island of Borneo. Although East Malaysia occupies the larger portion of Malaysia's total area, it is primarily comprised of undeveloped land and jungles. Hence about three-quarters of Malaysia's population of 23 million live in Peninsular Malaysia.

Being surrounded by sea, Malaysia has a coastline of 4 800 km. Within the coastal area, mangrove forests cover about 641 000 ha. Most mangrove forests are located in Sabah (57 percent), with 26 percent in Sarawak and only 17 percent in Peninsular Malaysia. Beyond the shore are over 200 islands with warm, clear waters and teeming marine life that have delighted tourists and divers.

The climate of Malaysia is tropical. The average temperature is between 21–32 °C. Humidity is high. Rain tends to occur between November and February on the east coast of Peninsular Malaysia, in western Sarawak and in northeastern Sabah. On the west coast of Peninsular Malaysia, the rainy seasons are April to May and October to November. With its favourable climate supported by vast natural resources, Malaysia has a great potential for aquaculture development.

Malaysia has the vision to become a developed country by the year 2020. The country recognizes the significance of sustainable aquaculture as an integral part of efforts to develop its natural resources. Malaysia is therefore giving high priority to increasing its aquaculture production, with most attention being given to shrimp and marine finfish aquaculture. Various institutions and governmental agencies have been given the task of commercializing this sector, getting involved in research, training and development. On the other hand, mindful of the rising labour shortage in Malaysia, the government's policy is to promote capital-intensive large-scale commercial shrimp farming. Mechanization and automation are promoted whenever feasible. Farms are encouraged to operate on an integrated and self-sustaining basis. Fry and feed production, processing and packaging, as well as marketing are built into vertically integrated systems. Malaysia is encouraging partnerships to achieve its aquaculture development objectives. The government is interested in attracting foreign capital and appropriate know-how to develop the sector through environmentally friendly technologies.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKET

An analysis of local and international demand, trade and market trends

Annually from 2002 to 2004, the production of fish from the marine sector in Malaysia was about 1.4 million tonnes with a value of slightly more than RM 5 billion. The bulk of production (close to 90 percent) came from capture fisheries. An average of 10 percent of the share came from aquaculture, amounting to about 1 200 to 1 400 tonnes, valued at RM 700–900 million annually over the last five years (Table 1). Brackishwater aquaculture contributed on average 70–75 percent of the total aquaculture production. In terms of quantity, about 30–40 percent and 10–20 percent of marine aquaculture production came from cockle rearing and seaweed cultivation, respectively. Pond-based production, which is typical of shrimp aquaculture, and cage systems contributed about 5 and 15 percent, respectively, in terms of quantity. Despite the low volume, products from this sector earn the highest trading values for fishery products.

As a source of cheap animal protein, fish is considered an important food item by the Malaysian people. Due to easy access to fish and fish products, Malaysia is among the countries with the world's highest fish consumption, having an average per capita consumption of 49 kg in the year 2000. This consumption increased to 53 kg per capita in 2005 and is expected to rise further to 56 kg per capita in 2010. The importance of fish as food is further reflected in household expenditure data, which show that on average, expenditures on fish account for about 20 percent of the household food budget (MOA, 2003). With increases in population and health consciousness among the Malaysian people, it is apparent that local production will not be able to meet the goal of self-sufficiency within the coming years. Self-sufficiency was only 89 percent in 2000. This figure was expected to increase slightly to about 90 percent in 2005 and predicted to increase further to 94.3 percent in 2010, if strategies and action plans put in place under the Third National Agricultural Policy (NAP3) new policy thrust are implemented and goals achieved.

TABLE 1
Fish production from marine landings and marine aquaculture, 2000–2004

Year	Landing		Aquaculture		Total	
	Volume (tonnes)	Value (RM million)	Volume (tonnes)	Value (RM million)	Volume (tonnes)	Value (RM million)
2000	1 285 696	4 399.23	117 205.56	665.34	1 402 901.56	5 064.57
2001	1 231 289	4 166.11	133 562.79	958.01	1 364 851.79	5 124.12
2002	1 272 078	4 206.81	145 439.81	843.49	1 417 517.81	5 050.30
2003	1 283 256	4 013.62	146 926.82	931.09	1 430 182.82	4 944.71
2004	1 331 645	4 241.45	146 668.04	903.38	1 478 313.04	5 144.83

The NAP3 (1998–2010) was formulated following the Asian financial crisis of 1997, which put pressure on food and the country's food import bill. In response, government strategies and implementing mechanisms for the NAP3 give special attention to agricultural development and the economy as a whole. Besides its traditional role in supplying food for the country, the sector was expected to enhance food security and increase its production and contribution. Secondly, the fishery sector was to become an engine to contribute to national income and export earnings. Thirdly, the sector was to maximize income of the producers and contribute to poverty alleviation. The expectations and hope put on the fisheries sector in the NAP3 were based on the sector and particularly, aquaculture, being able to produce food in a cost-competitive manner. The country was also recognized as having large areas suitable for the development of the aquaculture industry. Previous earning data also indicate that the fisheries sector is a clear contributor to the national economy (Table 2).

TABLE 2
Food export and import bills, 2004 (Source: MOA)

Commodity	Exports (RM million)	Imports (RM million)	Trade balance (RM million)
Livestock	1 005.2	2 696.3	-1 691.0
Fish products	2 073.0	1 935.0	137.9
Agricultural products	4 337.5	7 778.4	-3 440.9
Others	2 513.8	4 144.8	-1 631.0
Total	9 930.0	16 554.5	-6 625.0

Consumer trends, preferences, buying patterns

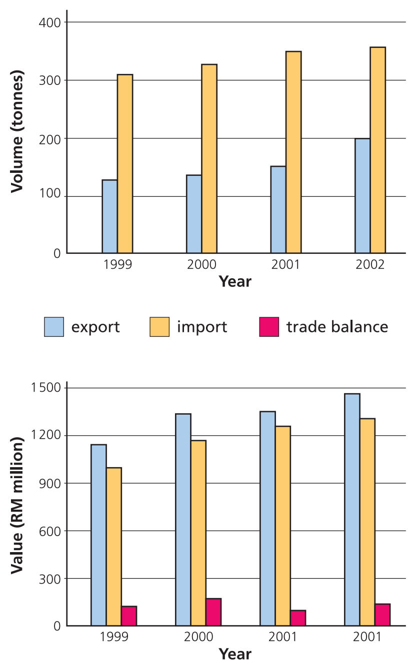
For a long time, most Malaysian consumers have preferred marine fish because of its taste, despite the much lower market price of freshwater fish. However, of late the influx of foreign workers, mainly from Indonesia and Bangladesh, has created a steady demand for freshwater fish. Locals are also starting to show a preference for freshwater fish due to better promotion by the government and dealers alike. As an indication, since 2001 freshwater fish production has shown a yearly increase of 8–12 percent. Most of the freshwater fish supply comes from the aquaculture sector, as Malaysia has little natural productive area. In 2003 the landing from inland fisheries was only 0.27 percent of the total fish production (Table 3). Most freshwater farmed fish are tilapia and African catfish.

Marine fish contributes to more than 70 percent of the local demand. Despite the volume, the species consumed are considered mainly lower grade, such as mackerel, sardines, scad and some tuna. Besides economic reasons, it is also worth noting that the eating habits and dining style of Malaysian people, especially the majority Malay ethnic group, are inclined towards serving small fish. The big or high-value aquatic products, such as crustaceans, are normally served in restaurants and are at high demand during festive seasons and ceremonies, especially among the Chinese community. Except for cockle and mussel, aquatic products from marine aquaculture generally do not supply the needs of ordinary people.

As a result of the continuously high demand for small and lower-grade fish species, Malaysia needs to import fish as a means to ensure enough supply for its people. On average, between 300 000–350 000 tonnes per year of fish and fish products were imported during 1999–2002. The import bills that came with this fish were between RM 1 000–1 300 million (Figure 1). Imported volumes came to about 406 000 tonnes in 2004 (Table 3), with an import bill of RM 1 935 million. The greatest portion of imported fisheries commodities came from neighbouring countries such as Thailand, Indonesia and Singapore, as well as from China (Table 4).

As a source of income, Malaysia exports most of its high-value fish to foreign markets. Among the commodities exported are shrimp, high-grade fish and molluscs (Table 4). The bulk of these commodities was sent to the United States of America (USA), followed by Singapore, Japan, the European Union and China. During the period 1999–2002, 130 000–190 000 tonnes of product were exported, with

Figure 1
Import, export and trade balance of fishery commodities



an export earning of RM 1 100–1 400 million. Subsequently, exports reached more than 238 000 tonnes with a value of RM 2 072 million in 2004. This trade brought in positive net earnings for the country of as much as RM 90–182 million during 1999–2004 (Tables 3 and 4).

TABLE 3
Main export and import fisheries commodities for Malaysia, 2004 (Source: DoF, 2004a)

Commodity	Exports		Imports	
	Volume (tonnes)	Value (RM million)	Volume (tonnes)	Value (RM million)
Live fish	8 332	74 941	4 502	24 792
Fish – fresh, chilled or frozen	79 836	188 526	317 892	980 719
Fish – dried, salted or in brine, smoked	1 495	9 351	1 834	9 254
Crustaceans & molluscs – fresh, chilled, frozen, salted dried	116 992	1 446 864	60 259	772 792
Crustaceans & molluscs – prepared or preserved	31 573	353 267	21 709	147 484
Total	238 229	2 072 229	406 190	1 935 041

TABLE 4
Malaysia's major trading countries, 2004

Export			Import		
Country	RM (million)	Value (%)	Country	RM (million)	Value (%)
USA	527 808	25.46	Thailand	465 146	24.04
Singapore	226 836	10.94	China	272 275	14.07
Japan	210 056	10.13	Indonesia	245 234	12.67
Italy	157 971	7.62	Singapore	161 722	8.36
China	112 297	5.42	Viet Nam	161 093	8.33
Others	837 982	40.42	Others	629 571	32.54
Total	2 072 950	100		1 935 04	100

Role of aquaculture in fisheries supply

Similar to other Asian countries, fish and fisheries products continue to play a vital role as a main source of cheap protein for the population. The fact that there is very little landing from inland fisheries and the preference of Malaysians is for marine fish mean that there is a need to increase production from the marine sector. Marine fisheries are faced with the problem of being exploited to the maximum and are unlikely to contribute further production. Reliance on deep-sea fisheries has not been taken seriously by locals. The deep-sea fishing fleet stood at only 761 units at the end of 2004 and as a small fleet, will not bring any significant changes to marine landings in the near future. Hence, the only option left is aquaculture, and in response the government has prepared strategies to develop marine aquaculture that are clearly defined under NAP3, as indicated earlier. The aquaculture sector is trusted with the task of enhancing food security and creating income to balance out food import bills (BOT), which have long been in deficit.

While recognizing aquaculture as one of the thrust areas for development, the Government of Malaysia is fully aware of the growing concern over sustainability and the environmental impacts of shrimp aquaculture. Human greed, coupled with profit-driven, irresponsible, short-sighted activities, is not to be allowed to tarnish the image of aquaculture. In a step towards realizing sustainable development, the impacts of aquaculture on coastal ecosystems, including mangroves, water and soil quality, as well as the socio-economic linkages in rural communities, are being carefully studied. The government is also interested in attracting foreign capital and appropriate know-how to develop this sector through environmentally friendly technologies.

Malaysia fully supports the initiatives taken by United Nations bodies, such as the Food and Agriculture Organization (FAO) to introduce the Code of Conduct for Responsible Fisheries (FAO, 1997). The government has already initiated steps to zone specific areas for aquaculture and develop standards for sustainable aquaculture practice that do not lead to ecological impacts. Legislative measures on a Code of Practice for Shrimp Aquaculture and establishment of fish health management programmes of international standard are under active consideration (FAO, 2004).

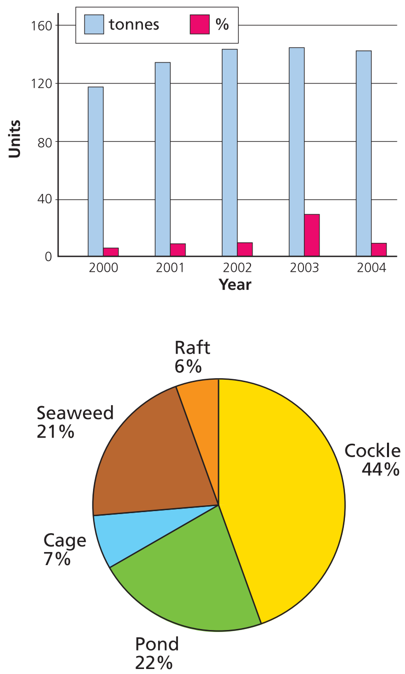
Production status

Marine aquaculture presently contributes about 133 000–146 000 tonnes annually. This represents about 28 to 33 percent of total fish production in the country (Figure 2). There are six major sectors that contribute to the production. The greatest production is contributed by traditional cockle cultivation, which accounted for about 44 percent in 2004. Pond production (mainly shrimp culture) contributed about 22 percent, followed by seaweed cultivation, with a share of about 21 percent. Production from cages (mainly finfish) and rafts (mainly mussels) each contributed about 6 and 7 percent, respectively.

Contribution to food security

Following a decision by the Malaysian government to increase fish production through aquaculture, various strategies were put forward under NAP3 and have been implemented since 1998. Marine shrimp, in particular, are given priority as a commodity with potential to generate income and hence contribute to foreign currency earning. However, the planned development has not met expectations due to problems with disease, land matters, market regulations and price fluctuations, as well as competition from labour-extensive countries. For such reasons, production from marine aquaculture between the years 2000 and 2004 as a whole did not show much development. An annual growth rate of about 20 percent was expected under NAP3; however, after an initial slight jump of about 13 percent in 2000, production from marine aquaculture did not show any further development up to 2004. The contributions were maintained in the range of 133 000 to 146 000 tonnes annually. From an increase of about 8 percent in 2002, the next three years showed an annual increase of only 1 percent (Figure 2).

Figure 2
Mariculture production and culture system contribution in 2004



Contribution to national economy

According to a recent fisheries statistical report (DoF, 2004a), fisheries production as a whole contributed between 1.37 to 1.73 percent to national gross domestic product (GDP) during the period 2002–2004. More than 85 percent of the contributions were from marine fisheries landings, and the contribution from the aquaculture sector as a whole was about 15 percent over the past four years or so. The majority or slightly more than 70 percent of the share originated from marine aquaculture. Further analysis estimates the GDP from marine aquaculture production at about 0.11–0.14 percent. These monetary gains were mainly generated from the trading of 145 000 to 147 000 tonnes of fish and fishery products with a wholesale value of RM 843.5 million to 931.1 million. In addition to generating income, the marine aquaculture sector provided job opportunities to about 4 000 to 4 200 people (Table 5 and 6), representing about 20 percent of the workforce in aquaculture-related activities during the last four-year period.

TABLE 5
Production, income (wholesale value) and labour involved in aquaculture activities, 2002–2004

	2002			2003			2004		
	1 000 (tonnes)	RM (million)	Labour	1 000 (tonnes)	RM (million)	Labour	1 000 (tonnes)	RM (million)	Labour
Inland	46.40	237.7	17 074	49.95	241.2	16 679	55.57	255.1	17 298
Marine	145.44	843.5	4 090	146.93	931.1	4 435	146.79	903.4	4 209
Total	191.84	1 081.3	211 644	196.87	1 172.3	211 144	202.24	1 158.5	2 507

TABLE 6
Contribution of marine aquaculture (in percentage) to fisheries and national economy, 2002–2004[1]

Parameter	2002	2003	2004
GDP	0.13	0.11	0.14
Employment in aquaculture	19.3	21.0	19.5
Fisheries	20.0	13.3	13.2
Volume (tonnes)	75.8	74.6	72.5
Value (RM)	78.0	79.4	78.0

[1] Note: Fisheries to GDP – 1.5% (2002), 1.37% (2003), 1.73% (2004).

The market chain organization, trend and vulnerability

Shrimp

Shrimp is considered marketable after a culture period of 120 days. Harvesting is usually done by draining the pond and attaching a net around the outlet pipe to trap the shrimp. The harvested shrimp is then washed using the waste water from the pond. The shrimp left in the pond are collected manually. Before harvesting, the buyers take a random sample to determine the average size and the price. The ex-farm price of black tiger shrimp (*Penaeus monodon*) of 40 pieces/kg ranges between RM 20–25, while that for white shrimp (*Litopenaeus vannamei*) of standard size (70 pcs/kg) bring an ex-farm price of between RM 12–15. Buyers provide ice, boxes and also transportation for the shrimp to be sent to processing plants. The distribution channel for cultured shrimp is straight forward; buyers are also processors or exporters. Most of the products are for the export market, and only a small quantity goes to local markets such as restaurants, hotels and retail chains. Despite the vast market, as elsewhere in Asia, the industry is vulnerable to threats from disease and the impact of fluctuating prices on the world market. There are also the issues of market regulation and traceability, which may slow down production from small-scale farmers. In terms of new area, not much can be developed if there is a boycott of shrimp from mangrove areas. Shrimp farming is further hindered by competition in terms of production cost among major producing countries. Malaysia is at a disadvantage in terms of labour. Most of the farms employ foreigners to run their operations, and as the government is tightening the entry procedure, the industry may have little space to remain competitive. One option is if Malaysia could make more efficient use of fuel to reduce costs of production.

Finfish

Marine finfish are considered marketable at about 500 g. However, different markets may require different sizes. Consumers in China, Hong Kong Special Administrative Region (SAR) prefer a size of 600 g to 1.2 kg for live grouper. There are two marketing channels, one to local markets and the other to overseas markets, mainly China, Hong Kong SAR. Species cultured for the local market are mostly seabass, various species of snapper and black grouper. The ex-farm price for seabass is between RM 12–14 per kg, while that for black grouper and snapper is between RM 18–25 per kg. The local market for live marine finfish is limited mainly to festivals, and the peak season for consumption is around January to March, coinciding with the Chinese New Year. On ordinary days the main outlets are Chinese seafood restaurants. The price of fish in restaurants is at least double that of the farm. Export markets are for fish of high-value such as tiger grouper and mouse grouper. The price reflects international market prices.

For live finfish, handling and packaging are given serious attention to ensure the best price. Shipment of fish from cages to local markets or to holding tanks or nets is done using trucks equipped with aerated seawater tanks. Shipment of live fish is done in two ways, either by packing in plastic bags or (typically involving large quantities) by live fish transport vessel (LFTV), usually owned by China, Hong Kong SAR importers. Fish in plastic bags are commonly transported as airfreight. They are placed at about 4–5 kg per bag in a four-layer plastic bag followed by a final packing into a styrofoam or cardboard box.

Fish farming for the live-fish market will not see a drastic scale up of production in the near future, as expected by the government and stipulated in NAP3. Foremost, it is constrained by seasonal demand and secondly, by the problem of meeting changing market demands that require multi-species production. In addition, the industry is vulnerable to shortages in supply of seed and space to expand operations. Disregarding the ever-changing species and seasonal demands, seed is still a major constraint in development of traditional fish such as seabass. While the number of suppliers is sufficient, most of them use a pond-based production system that is vulnerable to disease outbreaks and poor survival; hence the quality of seed delivered to farmers is poor. Seasonal demand and multi-species fish culture operations also affect the seed supply and the hatchery business; the seed producers thus are in a dilemma about upgrading their systems. Concerning the space available for grow-out, inshore areas are restricted and vulnerable due to their limited carrying capacity and increasing coastal water pollution. Deep-sea cages or land-based systems are needed for future development.

Molluscs

Cultivated cockles, green mussels and oysters are sold at local markets through middlemen. The retail price of a kg of cockle is RM 1.50–2.00. Raw mussels usually have a retail price of about RM 5.00/kg, while the dried form may fetch a retail price of about RM 12–15/kg. In terms of volume, fresh oyster is still small and mostly sent direct to seafood restaurants and hotels. Cockle cultivation depends largely on availability of suitable mudflat areas free of water pollution. Future plans to expand cockle, mussel and oyster culture will need to address constraints in seed supply, effects of harmful algal blooms and food safety issues. Food safety issues need to be addressed by rigorous environmental monitoring and quality controls.

Seaweed

Singularly a Sabah product, the main species used for commercial culture is *Eucheuma cottonii*. Environmental conditions around the Sabah coastline are generally favourable for culture of the species. Many of the operators are of Filipino ancestry. Seaweed is sold as a dried item. It takes approximately 9 kg of seaweed to produce a kilo of its dried form. Seaweed culture involves low capital investment and has a fast turn over. In general, seaweed production is still profitable at the steady production volume recently recorded (DoF, 2004a). Most seaweed from Sabah is sold for export, mainly to Denmark. Its dried form is sold directly to the exporter without using any middlemen. Usually the exporter assists farmers by providing aquaculture facilities, creating an obligation to sell the product back. The price of the dried form is about RM 1.50 per kg. Of late however, not many people want to get involved in seaweed culture because of better opportunities available in other sectors. Beside price incentive, commercial seaweed production is quite risky because of price fluctuations and the harvest being largely dependent on good sun-drying conditions. Future expansion needs to take into consideration conflicts with other resources users, including the tourism industry.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

Information on coastal communities

Most coastal communities earn a living from activities related to fisheries. The most common occupation of coastal inhabitants is that of fisherman. Other economically important activities include small-scale aquaculture and food processing related to fish products. Fishermen still dominate the traditional fishing sector. An unofficial estimate is that about 10 percent of the total of more than 80 000 fishermen fall into the "poor" category or are below the poverty level (RM 529 per month) (Table 7). People in this category are mostly employed on commercial fishing boats or as helpers on traditional fishing boats. They remain in these occupations because of their educational background. Data from reliable sources indicate that 50 percent of workers from coastal communities who are involved in the fishing industry have only a primary-level education. Close to 20 percent do not have any formal education or have never attended school at all. Due to their poor economic situations, about 20–25 percent do not own their own houses.

TABLE 7
Monthly income of various categories and levels of fishermen (RM)

Category	Owner	Skipper	Worker	Diver
Commercial	3 326.27	1 631.54	507.41	1 118.27
Traditional	816.15	623.17	417.47	266.25

The role of mariculture in poverty reduction

The implementation of commercial-scale aquaculture projects in coastal areas has good potential to contribute to food production and poverty alleviation in coastal communities, besides earning income for producers and generating foreign exchange for the country. Aquaculture activities can create employment for communities and hopefully provide workers with much better take-home pay and a less risky job than the capture fishing industry. In addition, infrastructure such as electricity supply and communication and road access can spur related economic activities that can have a direct impact on coastal communities. As envisaged by government, if the targeted aquaculture production is fulfilled, there is a possibility that the percentage of the population falling into poverty will drop drastically within the next few years (Table 8) and that poverty may be totally eradicated by the end of 2009, or before the final date of the Ninth Malaysian Plan.

TABLE 8
Predicted annual increment in aquaculture and poverty reduction in coastal fishermen (Source: MOA, 2003)

Subject	2004	2005	2006	2007	2008	2009	2010
Aquaculture production (tonnes)	200	200	300	400	500	600	600
Below poverty level (%)	20	15	10	5	2	0	0

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Training centres of excellence

Presently the Department of Fisheries (DoF) has two training centres to cater to marine aquaculture-related activities (DoF, 2006). Another such centre will be built within the next one to two years with a specialization in brackishwater grow out. Besides catering to local requirements, both centres also train overseas participants, mainly those under the Malaysia Technical Cooperation Programme (MTCP), which was established for aquaculture in 1989. One of the centres, which is situated in the north of Peninsular Malaysia (Kampong Pulau Sayak, Kedah), is the Institute of Marine Aquaculture (IAM), which started operation in 1987. Among the courses offered at the centre are marine finfish seed production, finfish aquaculture in cages, marine shrimp seed and grow-out programme, seed and grow-out production of oyster and mussel, and on-farm feed formulation (DoF, 2006). The second training centre for marine aquaculture in Malaysia is the Marine Finfish Production and Research Centre (MFPRC) at Tanjung Demong, Besut, Terangganu, located at the east coast of Peninsular Malaysia. Marine finfish fry production and cage-culture operations are offered as courses at MFPRC.

Existing and proposed alternatives for technology transfer mechanisms

In making a concerted bid to develop aquaculture into a major industry by 2010, the Government of Malaysia through DoF has put emphasis on acquisition of technology through research and development (R&D) and training mechanisms to acquire and transfer that technology.

Technology acquisition through R&D

Realizing that the private sector plays a critical role in spurring aquaculture development, but may not be keen to invest in research, the Government of Malaysia promotes the concept of joint research projects. The area where R&D support is most needed is in quality seed production, an example being the production of specific pathogen free (SPF) broodstock. The government has a commitment to provide high-grade broodstock to farmers as a means to facilitate farming with high-quality seed. To facilitate research on such topics, the government will develop the capability and skills of its staff in priority areas of biotechnology, genetic engineering, breeding and disease. At the same time, an out-sourcing mechanism may be adopted to bring in knowledge from outside of the country.

Training as a mechanism of transfer of technology (TOT)

The DoF is traditionally involved in providing knowledge and technology to current and potential aquaculturists. With an increase in demand from the industry and to fulfil the manpower requirements for future development, existing facilities are being upgraded and new ones will be built to enable more participant enrolment and improve access to knowledge. The training syllabus is improved and personnel are also being improved. The latest development is cooperation between DoF and the National Vocational Training Authority (MLVK) to launch a training school to produce qualified skilled manpower in various aquaculture fields.

Present training activities and likely future requirements

Currently DOF is officially conducting eight training programmes in brackishwater/marine aquaculture at two training stations (Table 9). The syllabus of these training programmes includes subjects such as disease diagnosis and water quality management. Future topics that most likely will be included are finfish broodstock management and spawning, and management and application of recirculating systems.

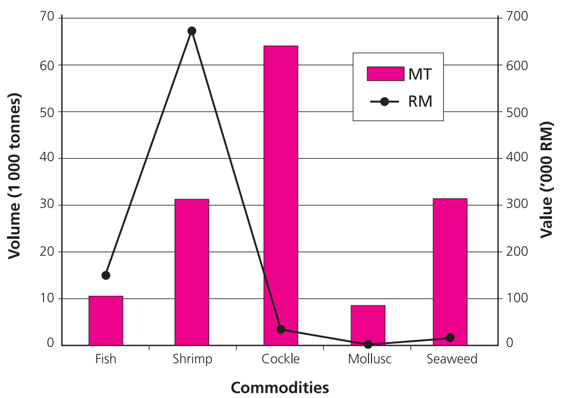
TABLE 9
Training programmes in marine aquaculture conducted by DoF in 2005

Title of training programme	Duration (days)	Intake per year (head)
Fundamental aquaculture practice	7	20
Seed production and management of marine finfish	30	15
Cage culture of brackishwater finfish	5	15
Seed production and management of marine shrimp	20	20
Culture and management of marine shrimp in pond	12	20
Feed formulation and preparation at farm scale	3	20
Seed production and culture of oyster	30	20
Seed production and culture of mussel	14	20
Giant freshwater prawn seed production	30	20

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Mariculture activities in Malaysia involve production of products from five major commodities: finfish, shrimp, cockles, other molluscs and seaweeds. Cockle farming produces the highest quantity of aquaculture product in terms of volume, with a production close to 64 560 tonnes in 2004. The next highest production was from seaweed cultivation with 30 960 tonnes. This was followed by shrimp production, which contributed 30 840 tonnes. During the same period, finfish culture brought in about 10 510 tonnes of fish, and harvest from other mollusc culture was 8 170 tonnes. Despite the volume, the income generated from the sale of cockle production was only third or RM 54.2 million. In general, shrimp production continues to dominate the income earned in aquaculture. In 2004 this was recorded at RM 656.5 million. The second highest income was from finfish culture at RM 157.48 million in the same year. Seaweed and molluscs generated an income of RM 15.48 and RM 4.60 million, respectively, in 2004 (Figure 3).

Figure 3
Quantity and value from mariculture production based on commodities, 2004



Status of farming of selected species

Marine shrimp

Species of interest

The sea around Malaysia is home to more than 15 species of shrimp classified as being of commercial importance. Five of these are of very high export value and form the backbone of seafood trading in the country: black tiger shrimp (*Penaeus monodon*), banana shrimp (*P. merguiensis*), Indian white shrimp (*P. indicus*), flower shrimp (*P. semisulcatus*) and greasy back shrimp (*Metapenaeus ensis*). Only *P. monodon* is cultured at commercial scale, although the popularity of this species is slowly being taken over by the white shrimp (*Litopenaeus vannamei*). The illegal introduction of this species was recorded in 2000. Despite being a prohibited species, illegal production during 2003–2005 was estimated at between 5 000 to 7 000 tonnes. Considering the yet unsolved disease problems in black tiger shrimp, the government finally decided to legalize the culture of *L. vannamei* effective from April 2004. Nevertheless, in a step to contain disease transmission, there is still a control on fry and broodstock entry into the country.

In Malaysia as in many countries that are traditional producers of *P. monodon*, *L. vannamei* is expected to play an leading role in the shrimp aquaculture industry in the years to come, unless efforts are made to revitalize the culture operations and disease control for the former. The DoF encourages Malaysian farmers to put interest on the culture of the Indian white shrimp, *P. merguiensis*; this local shrimp species was already being cultured at a small scale prior to the shift to *L. vannamei.* The product was sold as live shrimp and shipped mainly to Singapore. The poor farmer interest in *P. merguiensis* as an aquaculture species is due to its poor growth performance under high culture density. In the long run, however, this problem could be solved through a selective breeding programme. Such practices have proven effective in other shrimp species like *L. vannamei*, *L. stylirostris* and *Fenneropenaeus chinensis*.

Being a great income generator, the government hopes to increase shrimp production through aquaculture. Under NAP3, the target set was to achieve a production of 150 000 tonnes (Table 10) before or in year 2010. Concurrently, various contingency measures were undertaken, of which the most important was to increase the area under culture.

TABLE 10
Shrimp culture status in Malaysia, 1995–2004.

Year	Area (ha)	Farmers (number)	Shrimp production (tonnes)	
			Black tiger	White
1995	2 623	1 010	6 779	NA
1996	2 958	971	7 748	NA
1997	5 910	931	10 385	NA
2000	7 151		17 231	NA
2002	7 813	1 150	23 987	845
2003	7 011	1 239	25 375	804
2004	7 555	1 252	25 721	5 118
2010[1]	30 000	-	150 000	

[1] Projected figure based on NAP3 (1998–2010).

With the targets for production set in NAP3, it is estimated that a total of 30 000 ha of pond area is needed, a four-fold increase over the present area (Table 10). However, this target may take a longer time to achieve, due to land access constraints, diseases, market issues and regulation, plus the ever-increasing production from labour-extensive countries; the target can be partly achieved if a very drastic and holistic action is implemented.

Fry production

Presently there are about 50–60 shrimp fry production centres that supply the seed to shrimp grow-out farmers. They were originally intended for production of *P. monodon* but lately most of them have shifted to production of *L. vannamei*. In 2005, three hatchery facilities were granted permits to import SPF *L. vannamei* broodstock. On the government side, there is the National Prawn Fry Research and Production Centre (NAPFRE), a training and research facility for marine shrimp. There is also one fully biosecure hatchery system capable of production of clean/SPF *P. monodon* postlarvae (PL). In addition, there are also two or three other hatcheries with "partially" biosecure systems belonging to well-established aquaculture companies such as Charoen Pokphand and Grobest that still adhere to production of *P. monodon*. Overall, development in this sector at the small-scale level has been rather static because of inconsistent demand, strict quality requirements for fry and the demand for a warranty after some period in the pond. System-wise, most of the hatcheries are of the indoor type and are capable of producing 20–30 million PL per year.

Besides the use of chlorination to treat water, it is also common to see local hatchery systems equipped with extra gadgets such as ultraviolet light (UV) or ozone facilities. There is also a trend toward application of biotechnology products such as probotic bacteria, bioremediation and enzymes. Due to space limitations, most hatcheries use a single tank system to complete the fry production cycle. Only those few established hatcheries have separate larval and nursery tanks for this purpose.

With regard to *P. monodon*, the local supply of the broodstock is still sufficient. In fact, the interest in *L. vannamei* has seen the demand for *P. monodon* drop drastically from time to time. In terms of volume and quality, stock from East Malaysia, mainly from the waters off Sabah, is sought. Previously, broodstock from the Strait of Malacca were good enough, but lately most shrimp in this stock are found to be carriers of serious pathogens. As a biosecurity approach, it has already become normal practice for shrimp spawners to be screened for monodon baculovirus (MBV), whitespot syndrome virus (WSSV) and Tara syndrome virus (TSV). Except for small-scale operators who do direct spawning or purchase only nauplii, the procedure may not be adhered to so strictly. There are a few wild spawner collecting centres that deliver such products to small-scale operators. The price for a million nauplii of *P. monodon* is around RM 400–600, while gravid broodstock weighing 130–160 g are priced at RM 200–250 each.

Pond operation

In the past, a shrimp pond in Malaysia was synonymous with a mangrove swamp area. However, less critical and better areas such as coastal lands, abandoned coconut estates and paddy fields closer to infrastructure and facilities are now being developed. Water is supplied by means of a pump or via interconnected canals. Commercial farms integrate reservoir and sediment to ensure a supply of good-quality water for their operations. Separate inlet and outlet drains are normally installed. Be it a small-scale or a commercial operation, rectangular ponds of 0.5–1.0 ha dominate the present systems of operation. The depth is usually 1.2–1.5 m. Water exchange is less frequent and reservoirs are commonly used. Pond structure and design are of several types. Earthen ponds are most common, with plastic linings used on a small proportion of farms. Ponds with concrete wall structure are rather rare.

To sustain water quality and increase productivity, farmers invest in various biotechnology products. Some of these are bacteria-dominated compounds, enzymes, yeasts, inert feeds, simple sugars and vitamins. A common practice for tiger shrimp culture is to stock fry at PL stage 15–20; however, for *L. vannamei* this is done at PL 7–10. Under the present system, stocking rates are 30–40 per m^2 for *P. monodon* and up to 120 per m^2 for *L. vannamei*. Prior to stocking, responsible farmers will do acclimatization and selection as a final step to guarantee that only quality and healthy PL are stocked. PL are delivered by means of plastic bags. In a standard plastic bag of 5–8 litres, they are packed at 500–1 000 per litre. As a criteria for PL quality, farmers insist on a disease test and certification, besides adhering to physical, microscopic observation and stress test implementation. In ensuring sufficient oxygen supply, paddle wheels with single or double blades are installed, usually between 4–6 pieces per pond. In addition, long-arm paddle wheels of six or more blades are also installed at some corners to sweep and accumulate leftover feed from the feeding area. Feeding trays of 1 m^2 are commonly used, with between 4–6 per pond. Feeding commences with a rate of two times per day and is increased to four and up to six to eight times daily when shrimp are near harvesting size. During the farming process, various types of lime are applied to stabilize water pH. Harvesting usually commences when the shrimp attain a size of 30–50 pieces/kg for *P. monodon* and about 70 pieces per kilo for *L. vannamei*.

Marine finfish

Although marine fish farming has existed for the same length of time as marine shrimp farming, its development in Malaysia has been slower and less prominent. One of the primary reasons is that it was over-shadowed by the farming of black tiger shrimp, which once attracted many people as a fast and lucrative source of income. The fact that it is not a land-based activity, restricting it to a few suitable areas, has also constrained development. Marine fish farming is still at an infant stage, and thus the industry is still operated with traditional farming concepts. Almost all of the marine fish produced come from open floating net-cages, which are basically small to medium-size cage farms. As a commodity that contributes to national economic and food security, the government has targeted a production of 120 000 tonnes to be achieved by 2010 through aquaculture. Production presently amounts to about 10 500 tonnes (Table 11). In terms of value, the sale of cultured marine finfishes brought in about RM 158 million as income to the country, an increase of about 24 percent from year 2002. Hence, with the targeted and increasing demand for fish, there is a need to change the concept of marine fish farming from that of subsistence farming to a commercial scale.

TABLE 11
Production (tonnes) and wholesale value (RM million) of the main cultured fish species, 2002–2004

	Production (tonnes)		
Fish species	**2002**	**2003**	**2004**
Asian seabass	4 003.73	4 210.93	4 000.54
Mangrove snapper	591.44	706.56	572.97
Yellow snapper	1 556.15	2 351.55	2 263.33
Red snapper	989.68	1 402.09	1 162.85
Grouper	1 210.43	1 977.33	2 283.59
Tilapia	283.97	222.07	264.42
Total	8635.4	10 870.53	10 547.7

	Value (RM million)		
Fish species	**2002**	**2003**	**2004**
Asian seabass	46 220.13	49260.86	46 241.57
Mangrove snapper	6 157.05	8 415.69	7 742.36
Yellow snapper	20 188.00	32 491.55	32 771.81
Red snapper	12 951.31	18 513.27	14 687.02
Grouper	30 385.26	49 954.09	54 628.69
Tilapia	1 683.98	1 049.09	1 387.08
Total (x1 000)	117 585.73	159 684.55	157 458.53

Species of interest

In Malaysia, marine fish farming started with the culture of Asian seabass (*Lates calcarifer*) during the 1970s. As in other Asian countries, this sector is characterized by the culture of a range of fish species regarded as high value. The choice of which species to culture is related to availability of seed and the ever-changing preferences of consumers in China, Hong Kong SAR and Singapore. The species cultured by farmers are also switched when current stocks are affected by disease problems. Over the last five years, the number of species being farmed has increased drastically following the success of breeding programmes, both locally and elsewhere. At least ten species of fish are presently cultured throughout the country. The leading species remains the Asian seabass., followed by the snappers (Lutjanidae), which include yellowstreaked snapper (*Lutjanus lemniscatus*), mangrove red snapper (*L. argentimaculatus*), John's snapper (*L. johni*) and crimson snapper (*L. erythropterus*) (Table 12). The interest in grouper has led to at least six species being introduced for farming. Among the groupers commonly cultured in Malaysia are brown-marbled grouper (*Epinephelus fuscoguttatus*), orange-spotted grouper (*E. coiodes*) and Malabar grouper (*E. malabaricus*). Other minor species are fourfinger threadfin (*Eleutheronema tetradactylum*), cobia (*Rachycentron canadum*), snubnose pompano (*Trachinotus blochii*) and red tilapia (*Oreochromis* sp.).

TABLE 12
Finfish species of interest for mariculture in Malaysian waters

Species	Common name
Seabass	
Lates calcarifer	Asian seabass
Snapper	
Lutjanus lemniscatus	Yellowstreaked snapper
L. argentimaculatus	Mangrove red snapper
L. johni	John's snapper
L. erythropterus	Crimson snapper
Groupers	
Epinephelus coiodes	Orange-spotted grouper
E. malabaricus	Malabar grouper
E. sexfasciatus	Sixbar grouper
E. fuscoguttatus	Brown-marbled grouper
Cephalopholis leopardus	Leopard hind
Cromileptes altivelis	Humpback grouper
Threadfins	
Eleutheronema tetradactylum	Fourfinger threadfin
Cobias	
Rachycentron canadum	Cobia
Tilapias	
Oreochromis sp.	Red tilapia
Pompanos	
Trachinotus blochii	Snubnose pompano

Seed production

Seed supply is still a constraint to the development of marine fish culture in Malaysia. A significant amount is still being imported from neighbouring countries such as Indonesia, Thailand, Singapore and Taiwan Province of China. Beside seed, eggs are also brought in. At present, local seed production centres are still too small to supply the demand, especially when dealing with the multi-species way of fish production. Additionally, most hatcheries are still crude in approach and hence do not always meet the requirement to supply good-quality seed for sustainable grow-out farms. To supplement the demand, there are two typical seed production systems employed, the tank or hatchery system and the pond-based system. Unofficial records indicate that 12 land-based fish hatcheries are currently in operation. Two of them are government research and training centres that occasionally distribute their produce to farmers. Each private hatchery has a capacity to produce some 0.5–2.0 million fry per year. Some of the hatcheries maintain broodstock, whereas others still need to acquire eggs from outside.

To supplement the seed supply, there are more than 50 fry production units that use earthen or partially concreted ponds as their production system. Each unit employs 3–10 ponds of 0.1–0.5 ha on average. The operation starts with the hatching of eggs in a *hapa* installed in the pond or in separate tanks close to the pond. The fry are released into the pond a few days after hatching, when they are ready to consume outside food. Ponds are enriched with live food by means of organic or inorganic fertilizers before stocking of newly hatched fry. Being low-capital and food-chain based, survival from this production system is on average between 1–5 percent. Sometimes, when natural food availability is not sufficient, nothing is produced. Nevertheless, production from this sector is quite significant, with each farm producing 0.2–1.0 million fingerlings per year.

Broodstock and egg production is another part of the production system that is improving. Currently eggs are distributed by breeders who keep the broodstock in floating cages. Egg production normally comes from the process of natural spawning. The operators need to keep a large number of spawners so that there are sufficient fish ready to release eggs when needed. Upon spawning, the eggs are collected by net. Although wild-caught spawners are preferred for egg production, broodstock often come from normal cage production. The price of a million eggs varies from RM 500–3 000, depending on fish species.

Farm operation and production

The main production system for marine fish is still the floating net-cage. Pond production has not yet been given due consideration, despite the volume it can produce; pond production may yet be suitable for high-value fish species that require water of higher salinity than that found in many inland ponds. However, fish raised by pond culture are susceptible to off-flavour, and thus this method may not be suitable as a system for the live fish market. Seeing the potential, the venture into mass production using deep-sea cages was initiated by the government through the DoF a decade ago. Since then, however, there has not been much development. The main reason seems to be an insufficient supply of fry. The demand in terms of number and quality is not yet matched. Apparently, this is due to this being a multi-species style of production. As of the end of 2005, there were 100 units of square-type cages measuring 6x6 m each and a total of 21 units of round type with a diameter of 15 m each. All of these cages were harboured at Langkawi Island, in northern Peninsular Malaysia. As they still face some technical problems, the cages are operated at under capacity most of the time.

Until a new system of fish production or cage-culture technology is introduced, traditional floating cages will continue to be the core marine fish production system in Malaysia. As of 2003 and 2004, there were a total of 1.0 million m^2 of cage area, an increase of about 14 percent from 2002 (Table 13). These cages were run by about 1 400 and 1 600 operators, respectively, during the production years of 2002 and 2003–04 (Table 13). Most operators are small-scale farmers running small (3x3 m) to medium-size (6x6 m) cage farms. Stocking densities vary from 300–1 000 fingerlings per cage. The culture period extends from 6–12 months, depending on species. Trash fish remains the major feed type, and only on occasion is supplementary commercial feed used. Farmers still find it difficult to change to pelleted feed, which would be a better option for disease control and environmental management. The main reason is the cheap price of trash fish and that the supply is readily available. Many farmers also still believe that feeding with trash fish produces a fish preferred by the market in terms of quality and texture.

In recent years, due to increasing intensification in production and area, cage farming has faced many disease problems. As a result, there were regular records of mass mortality that were related to water quality and oxygen depletion. The die-hard farmers seem to take this for granted and are willing to invest in a new operation for the sake of fish production.

TABLE 13
Facilities and operators involved in marine fish farming, 2002–2004

Facilities	2002	2003	2004
Hatcheries (unit)	12	59	56
Cages (m^2)	940 948	1 034 664	1 110 221
Cage operators (head)	1 374	1 651	1 623

Molluscs

Malaysia has a long tradition of mollusc culture. In terms of quantity, cockle contributes about 40 percent of the harvest from the aquaculture sector. Over the past three years, the annual production from cockle was about 70 000 tonnes (Table 14). The value from the sale of cockle during 2004 was about RM 54 million. The total area used for the cultivation of cockle is presently about 7 000 ha, and there are about 300 operators cultivating this commodity. Mussels, which come next in terms of production, were harvested in the range of 6 000–7 000 tonnes, whereas around 250–285 tonnes of oyster were produced annually during 2002–2004. Both mussel and oyster are cultured in rafts with about 100 000–150 000 m^2 and 100 000 m^2 of area, respectively, being dedicated to their production. The number of operators involved in their culture during the last three years is about 300–350 and 260–300, respectively, for mussel and oyster production (Table 14). In term of revenue, both commodities created income of about RM 5 million during 2004.

TABLE 14
Production, areas and number of operators involved in mollusc aquaculture, 2002–2004

	Production (tonnes)		
Commodity	**2002**	**2003**	**2004**
Cockle	78 706.64	71 067.29	64 564.75
Mussel	5 919.85	7 701.73	7 904.76
Oyster	285.66	256.43	260.68
Total	84 912.15	79 025.45	72 730.19

	Area and operators					
Commodity	**2002**		**2003**		**2004**	
	Area	**Operators**	**Area**	**Operators**	**Area**	**Operators**
Cockle	6 891.2 ha	297	7447.1 ha	311	6662.7 ha	276
Mussel	82 186 m^2	288	109 817 m^2	347	156 799 m^2	357
Oyster	103 145 m^2	264	103 212 m^2	282	104 008 m^2	309
Total		849		940		942

Seaweed

Compared to other marine aquaculture products, seaweed culture is localized in one state, Sabah, and in only one area, Semporna. Culture of the commodity has a long tradition, and between 2002 and 2004 its annual production increased from 26 000 to about 31 000 tonnes, despite a decrease in the culture area from 1 900 ha to about 1 000 ha (Table 15). There was also a drop in the number of operators involved in cultivation, from about 712 in 2002 to about 392 in 2004. In terms of quantity, seaweed cultivation contributed about 21 percent of the share of production from the marine aquaculture sector. The value from the sale of seaweed in 2004 was about RM 15.48 million.

TABLE 15
Seaweed aquaculture, 2002–2004

	2002	**2003**	**2004**
Volume (tonnes)	25 624.92	27 607.90	30 956.90
Area (ha)	1 908.32	1 206.25	986.02
Operators (no.)	712	605	392

PRIORITIES FOR RESEARCH AND DEVELOPMENT

Being a sector that traditionally supplies food and continuously contributes to the national economy, aquaculture was recently given special attention by the Government of Malaysia. The strategy and action plan to develop the sector was clearly spelled out in the Third National Agricultural Policy (NAP3, 1998–2010), a long-term plan for agricultural development. A volume of 600 000 tonnes was set aside for the aquaculture sector to deliver by the year 2010. Based on the annual fisheries statistics, the current achievement is around 202 225 tonnes. Hence, an additional 400 000 tonnes is necessary to achieve the target. With another five years to go, an annual production growth of about 22 percent will be necessary. In the marine sector, the two top-most income-generating commodities, shrimp and finfish, were assigned production targets of 120 000 and 150 000 tonnes, respectively. Presently these commodities have achieved production of only about 10 500 and 32 000 tonnes, respectively; thus, there is a long way to go to achieve the target. While a massive increment in production will no doubt come from increasing the area under culture, most new production will probably be from intensification of existing culture practices.

Marine shrimp

The major constraint in the development of traditional black tiger shrimp culture is disease. Hence, research on the following should be given due consideration:

- production of SPF broodstock and disease-free PL;
- application of better management practices (BMPs);
- automation towards reducing production costs; and
- development of sustainable production systems.

While aquaculture of the traditional shrimp species needs to be scrutinized and its problems solved, the importance of indigenous shrimp species such as the banana shrimp (*Penaeus merguinsis*) should be given due consideration to create interest for commercial production. This will create diversity of choice while slowly getting away from the culture of the exotic *Litopenaeus vannamei*. Promoting commercial culture of the species will mean that research must to go all out to solve the problem of poor growth performance under high density culture and to realize a culture period of 120 days, an established benchmark for many shrimp farmers in Malaysia.

Research on the following should be given due consideration:

- domestication and selective breeding programme;
- development of suitable feed; and
- development of culture technology.

Marine finfish

Being at a pioneer stage in the marine finfish industry, Malaysia can learn a lot from the stories of successes and failures in the shrimp industry. Foremost, seed should be of high quality and if possible free of serious pathogens (SPF). To pursue this goal, a domestication and selective breeding programme should be given high priority, along with improved biosecurity.

With regard to developing the subsector, the foremost priority should be a focus on the specific species to be developed. The live fish market cannot be relied upon to expand the market significantly, and attention should be given to the frozen fish market, the main agenda being to diversify the market through value-added products and to develop varieties to increase consumption by local consumers. Land-based production systems, i.e. ponds or tanks, should be examined as a means of production, as environmental problems may no longer permit the use of waterways for cage operations. Foreseeing the future problems, priorities in research and development (R&D) are considered to be:

- R&D for selected fish species;
- development of a broodstock bank;
- R&D in domestication and a selective breeding programme;
- development of a biosecure fish fry production centre;

- R&D in live food production;
- R&D in grow-out production facilities; and
- R&D in nutrition and feed formulation.

Identification of better management practices to mitigate environmental impacts

As a means to mitigate environmental impacts, the DoF in Malaysia has come out with a Guideline on Good Aquaculture Practices (GAP). Mainly for the shrimp industry at this moment (FAO, 2003), this guideline upholds the standards recommended by international bodies such as the FAO. Similar guidelines soon will be developed for marine finfish aquaculture and other culture systems. A major task for government is to ensure that the guidelines are adopted by aquaculturists, particularly the small-scale farmers. At this stage, the guideline is still difficult to implement because of a "free-for-all" situation that has existed for a long time. Lack of institutional and legal support may jeopardize the action plan or else local governments will have to impose rules for domestic food safety standards from aquaculture, as are being required by many importing countries. Large-scale operators, however, implement good aquaculture practices on their own initiative, so as to comply with the requirements for quality fish and shrimp products for the export market. To be part of the food production chain, one has to have standards and environmentally friendly production protocols.

Along this line, DoF Malaysia has introduced the Farm Certification Scheme or SPLAM (DoF, 2004b). The objective of SPLAM is to provide official recognition to aquaculture entrepreneurs who practice GAP and environmentally friendly concepts to ensure the safety, quality, consistency and competitiveness of their products based on the criteria, guidelines and standards determined by DoF. Farmers can obtain quality certification for their products after a period of quality assessment by authorities. Among the benefits derived from participating in the SPLAM programme are assurances that the farm's aquaculture products meet the food safety standards required by the domestic and international markets. Secondly, the programme assists and expedites the issuance of health certificates and sanitary and phytosanitary (SPS) certificates, so that this does not solely depend on final product testing. The third benefit is to encourage consumer acceptance of aquaculture products from local farms. Finally, the programme will assist the aquaculture industry to develop in a sustainable and environmentally friendly manner.

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INTRODUCTION

For the past several years, aquaculture has dominated the fisheries sector and is considered at the forefront of the government's food security and poverty alleviation programmes. Seaweeds and milkfish are the top-two commercially important species produced from aquaculture. Other species are tilapia, grouper, siganids and mussels.

With the vast growing population of the country, the need to expand aquaculture areas is obvious, from the traditional freshwater and brackishwater ponds to marine farming in fish pens and cages. The increasing volume of produce from cages compared to the modest production from fishponds has encouraged fish farmers to venture into deep-water-based or off-shore aquaculture enterprises.

The proliferation of fish pens and fish cages in shallow, narrow tributaries and rivers has resulted in occasional fish kills. These structures have obstructed the tidal flow of freshwater into brackishwater ponds, thereby affecting pond production in some areas. Moreover, polluted water caused by excessive feed inputs resulted to some extent in retardation in the growth of oysters. The continuous increase in the number of structures may also have contributed to siltation in aquaculture zones.

The establishment of mariculture parks is foreseen to play a significant role in solving these negative impacts. It also aims to promote zoning in municipal waters by delineating areas for mariculture and providing opportunities for marginal farmers to engage in off-shore fish-cage operation.

This paper will include information on the current status and challenges in the establishment of mariculture parks including the management concepts, legal mandates, organization, technical services offered, opportunities, constraints and issues.

OVERVIEW OF THE FISHERIES SECTOR

Contribution to world production

In 2003, the Philippines ranked eigth among the top fish-producing countries in the world, with a total production of 3.62 million tonnes of fish, crustaceans, molluscs and aquatic plants. The production constitutes 2.5 percent of the total world production of 146.27 million tonnes (FAO, 2004).

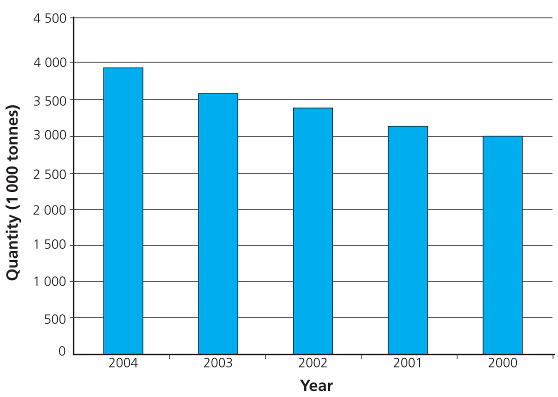
The Philippines aquaculture production of 0.459 million tonnes in 2003 was eleventh in the world, contributing 1.1 percent to the total global aquaculture production of 42.3 million tonnes and amounting to about US$600 million in terms of farm-gate value (FAO, 2004).

The Philippines is also the world's second-largest producer of aquatic plants (including seaweeds), having produced a total of 0.989 million tonnes or nearly 8 percent of the total world production of 12 million tonnes (FAO, 2004).

TABLE 1
Five-year fish production trend, 2000–2004 (Source: BFAR, 2004)

Year	Quantity (tonnes)	% Increase (Decrease)	Value (1 000 PHP)	% Increase (Decrease)
2000	2 993 332.00	2.38	98 622 134.00	6.82
2001	3 166 530.00	5.79	106 944 716.00	8.44
2002	3 369 524.00	6.41	113 258 218.00	5.90
2003	3 619 282.38	7.41	119 866 326.00	5.83
2004	3 926 173.36	8.48	138 846 377.29	15.83

Figure 1
Five-year fish production trend, 2000–2004



Contribution to national economy

In 2004 the fishing industry contributed 2.3 percent and 2.4 percent to the country's gross domestic product (GDP), equivalent to some PHP 111 billion and PHP 48 billion for current and constant prices, respectively (Table 1 and Figure 1).

The industry's contribution to the Gross Value Added (GVA) in Agriculture, Fishery and Forestry Group is 14.9 percent (PHP 111 billion) and 21.6 percent (PHP 48.7 billion) out of the total PHP 742 billion and PHP 225 billion at current and constant prices, respectively. It has the largest share next to agricultural crops.

The fishing industry provided employment to a labour force of more than 1.6 million nation wide (NSO 2002). Of the total labour force, 1.3 million are employed in the municipal fisheries, 226 195 in commercial fisheries and 16 497 in the aquaculture sector.

Performance of the fishing industry

In 2005, the total fisheries production reached 4.16 million tonnes (Table 2). In that year, the aquaculture sector provided the highest share of 45.5 percent, while commercial and municipal fisheries contributed 27.3 percent and 27.2 percent, respectively.

Total fisheries production grew from 3.17 million tonnes in 2001 to 4.16 in 2005. The average total annual production within the period 2001–2005 was 3.648 million tonnes.

From 2001 to 2005, the contribution of aquaculture to total fish production increased steadily from 38.5 percent in 2001 to 45.5 percent, for a five-year average contribution of 41.6 percent to the total production (Table 2). In comparison, commercial and municipal fisheries productions have similar contributions of about 30 percent and 29 percent, respectively, to the total fish production. Within the aquaculture subsector, production grew at an average rate of 11.6 percent per year between 2001 and 2005. The aquaculture growth rate in fish production in 2005 was a 10.4 percent increase over the year 2004.

TABLE 2
Volume (x1 000) of fish production by subsector, 2001–2005 (Source: BFAR, 2004 and preliminary data from Bureau of Statistics)

Year	Total production (tonnes)	Commercial		Municipal		Aquaculture		
		Volume (tonnes)	% of Total	Volume (tonnes)	% of Total	Volume (tonnes)	% of Total	Annual growth (%)
2001	3 166	976	30.8	969	30.6	1 221	38.5	10.8
2002	3 369	1 042	30.9	989	29.4	1 338	39.7	9.6
2003	3 619	1 109	30.6	1 055	29.2	1 454	40.2	8.6
2004	3 924	1 137	28.9	1 059	26.9	1 726	43.9	8.7
2005	4 163	1 135	27.3	1 132	27.2	1 895	45.5	10.4
Avg.	3 648	1 079.8	29.7	1 040.8	28.7	1 526.8	41.6	9.6

Marine waters production

Production in 2004 reached 23 542.35 tonnes in marine cages and 14 294.42 tonnes in pens. Commodities produced include milkfish, grouper and other marine species (Table 3 and Figure 2).

TABLE 3
Production (tonnes) from marine waters, 2004 (Source: BFAR, 2004)

Culture environment	Total	Milkfish	Grouper	Others
Fishcage	23 542.35	23 179.06	136.45	226.84
Fishpen	14 294.42	14 172.61	33.69	88.12
Total	37 836.77	37 351.67	170.14	312.96

Brackishwater production

For the year 2004, production from brackishwater fishponds was 253 848.52 tonnes, the bulk of which was the production of milkfish. Fish pens recorded a production of 4 499.50 tonnes, while fish cages added about 4 205.71 tonnes. Commodities from brackishwater production are milkfish, tiger prawn, white shrimp, endeavour prawn, tilapia and other species (Table 4 and Figure 3).

Figure 2
Production from marine aquaculture in 2004

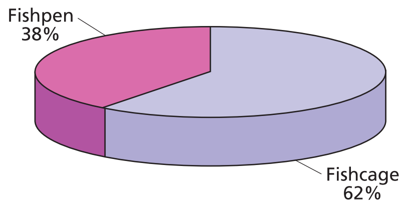


TABLE 4
Production (tonnes) from brackishwater, 2004 (Source: BFAR, 2004)

Culture environment	Total	Milkfish	Tiger prawn	White shrimp & endeavour prawn	Tilapia	Others
Fishpond	253 848.52	200 530.90	35 916.52	2 029.60	9 045.93	6 325.57
Fishcage	4 205.71	4 056.08	-	-	115.90	33.73
Fishpen	4 499.50	4 388.30	-	-	97.30	13.90
Total	262 553.73	208 975.28	35 916.52	2 029.6	9 259.13	6 373.20

Mariculture production

Regional production from mariculture yields a total of 1 235 761.09 tonnes. Seaweeds contributed the largest share of 97.5 percent. The rest is contributed by oysters and mussels, with percentage shares of 1.3 percent and 1.2 percent, respectively (Table 5). Regional production trend showed that the Autonomous Region in Muslim Mindanao (ARMM) remained the highest contributor of mariculture products, followed by Regions IV-B and IX, respectively (Figure 4).

Figure 3
Production from brackishwater, 2004

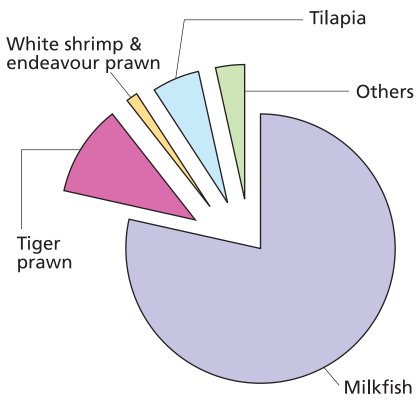


TABLE 5
Production (tonnes) from mariculture by region and commodity, 2004 (Source: BFAR, 2004)

Region	Total	Oysters	Mussels	Seaweeds
I	2 704.65	2 677.15	-	27.50
II	325.50	319.00	-	6.50
III	6 772.77	6 147.10	598.30	27.37
IV-A	30 008.44	343.44	4 227.00	25 438.00
IV-B	329 140.43	-	-	329 140.43
V	17 748.99	47.02	735.17	16 966.80
VI	62 971.60	5 354.73	6 633.25	50 983.62
VII	83 594.05	187.94	-	83 406.11
VIII	16 213.00	2.00	2 840.00	13 371.00
IX	155 102.67	312.21	4.50	154 785.96
X	39 155.64	-	-	39 155.64
XI	1 670.36	524.72	-	1 145.64
ARMM	472 514.80	-	-	472 514.80

Figure 4
Total production (tonnes) from mariculture by region, 2004

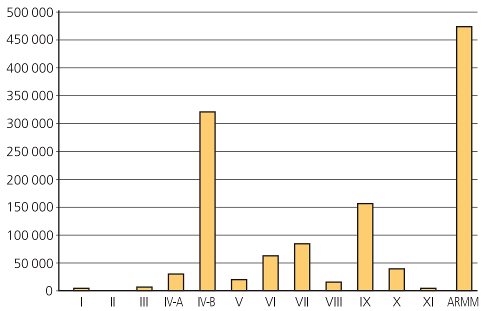
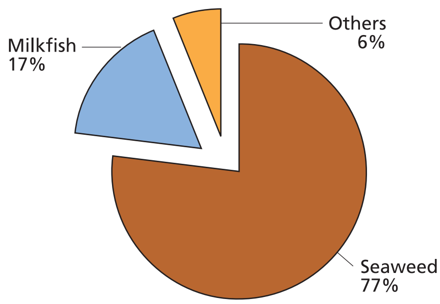


Figure 5
Major farmed species in 2004



Commodities

The top three major aquaculture commodities are seaweeds, milkfish and tilapia (Table 6 and Figure 5). Seaweeds recorded the highest volume, constituting 70.2 percent of the total aquaculture production. Milkfish ranked second with a share of 15.9 percent, followed by tilapia with 8.5 percent. The rest contributed 5.4 percent.

TABLE 6
Major species produced by aquaculture, 2004 (Source: BFAR, 2004)

Species	Quantity (tonnes)	Percent (%)
Seaweeds	1 204 807.56	70.2
Milkfish	273 593.36	15.9
Tilapia	145 860.36	8.5
Others	92 757.38	5.4
Total	1 717 026.66	100

Seaweeds

In the Philippines, seaweed is the most valuable commodity produced from aquaculture. More than 800 species of seaweed have been recorded in the Philippines. The major commercial seaweeds are *Eucheuma, Kappaphycus, Gracilaria* and *Caulerpa*. Others include *Codium, Gelidiela, Halymenia, Porphyra* and *Sargassum*.

Production of seaweeds has continuously increased from 707 039 tonnes in 2000 to 1 204 808 tonnes in 2004. The yearly improvement in production can be attributed to high market demand, better prices and good weather conditions that encouraged farmers to expand their areas for seaweed culture.

TABLE 7
Seaweed production, 2000–2004 (Source: BAS and BFAR, 2005b)

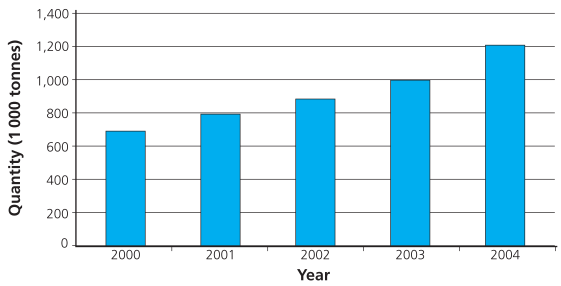
Year	Production (tonnes)
2000	707 039
2001	785 795
2002	894 856
2003	988 888
2004	1 204 808

Seaweed culture is now emerging as an important and major livelihood in the coastal areas, specifically in Regions ARMM, IV-B and IX. The provinces of Tawi-Tawi, Sulu, Basilan, Palawan, Antique, Bohol, Quezon, Zamboanga del Norte, Camarines Sur, Eastern Samar, Surigao del Sur, Zamboanga Sibugay, Lanao del Norte and Maguindanao are potential areas for seaweed culture.

Seaweeds contributed 31 percent to the total 2004 fisheries production (Table 7 and Figure 6). *Kappaphycus alvarezii* and *Euchema denticulatum* are the major species cultivated. The culture methods used by farmers are fixed bottom monoline and floating monoline.

The seaweed industry employs between 100 000 and 120 000 people. Of the total individuals employed, 90 percent are seaweed farmers and the rest are seaweed processors and traders. Sixty-five percent of the total production is processed into semi-refined chips/carrageenan, 13 percent is exported raw (dried) and the remaining 22 percent is processed into refined carrageenan.

Figure 6
Five-year fish seaweed production, 2000–2004
(Source: BFAR, 2004)



The Philippines is among the top producers of seaweeds in the world, specifically the red seaweeds – next to the People's Republic of China and Japan. In 2004, about 24.8 million tonnes valued at PHP 1.2 billion was exported to the United States of America, France, Republic of Korea, China and China, Hong Kong SAR.

Problems and constraints

The main problems facing seaedweed cultivation in the Philippines are:

- pollution in production areas;
- inadequate supply of dried seaweeds for processing leading to processors' losses;
- the peace and order situation in seaweed-producing areas;
- diseases affecting seaweeds (e.g. ice-ice);
- inconsistency in quality due to adulteration of the processed product with foreign materials; and
- increasing competition in *Eucheuma* production from other countries such as Malaysia, Indonesia and some African nations.

Milkfish

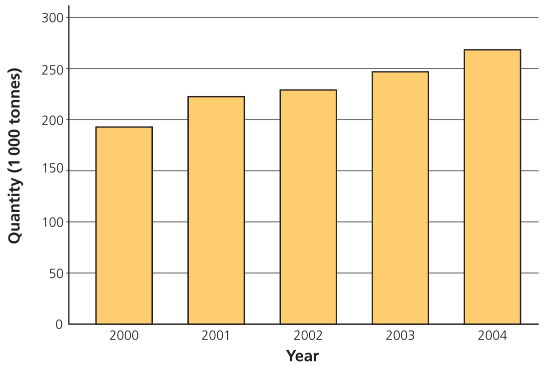
Milkfish is an important aquaculture commodity. Over the past five years, production has steadily increased from 194 023 tonnes in 2000 to 269 930 tonnes in 2004, with an average annual growth rate of 8.7 percent (Table 8 and Figure 7). Harvests from the different culture environments were as follows:

- freshwater contributed 10 percent to the total milkfish production;
- brackishwater recorded the highest share of 77.4 percent due to improved technology such as increase in stocking density and expansion of operations; and
- marine fish cages and fish pens contributed 12.6 percent.

TABLE 8
Milkfish production, 2000–2004 (Source: BFAR, 2005a)

Year	Production (tonnes)
2000	194 023
2001	225 337
2002	231 968
2003	246 504
2004	269 930

Figure 7
Five year total milkfish production, 2000–2004
(Source: BFAR, 2004)



Based on regional milkfish production and requirements in the year 2004, regions I, III, IV-A & B, VI, IX, XI and XII recorded a surplus, while deficits were incurred in regions II, NCR, V, VI, VII, VIII, X, ARMM and Caraga. However, based on the national production, a surplus of more than 100 000 tonnes was determined (Table 9).

TABLE 9
2004 milkfish production and requirements at 1.98 kg per capita consumption (Source: BAS, 2004; BFAR, 2005a)

Region	Population	Production (tonnes)	Consumption (tonnes)	Gap
I	4 422 483	48 634.3	8 756.5	39 878.1
II	3 032 872	240.4	6 005.1	(5 764.7)
III	8 297 012	58 794.0	16 428.1	42 365.9
NCR	11 070 287	3 160.0	21 919.2	(18 759.2)
IV-A	10 940.575	32 665.9	21 662.3	11 003.6
IV-B	1 612 601	3 582.7	3 192.9	389.8
V	5 079 867	1 669.9	10 058.1	(8 388.2)
VI	6 778 143	63 991.7	13 420.7	50 571.0
VII	5 970 149	7 582.0	11 820.9	(4 238.9)
VIII	4 058 787	2 362.4	8 036.4	(5 674.0)
IX	3 452 079	9 776.3	6 835.1	2 941.2
X	3 013 186	5 907.4	5 966.1	(58.7)
XI	5 771 878	12 446.9	11 428.3	1 018.6
XII	2 910 459	13 311.7	5 762.7	7 549.0
ARMM	2 330 394	2 004.6	4 614.2	(2 609.6)
Caraga	2 393 402	3 799.7	4 738.9	(939.2)
Total	82 663 599	269 930.2	163 673.9	109 284.5

Problems

Problems faced by milkfish culture in the Philippines include:

- degradation of quality fingerling stocks due to inbreeding;
- insufficient supply of quality milkfish fry in far-flung areas;
- high cost of farm inputs and poor quality feeds;
- lack of manpower to effectively transfer technology to the municipal level; marketing layers that stand between producer and consumer; and
- lost opportunities to participate in the global market for value-added products.

GOVERNMENT PROGRAMMES/INTERVENTIONS

Seaweeds

Interventions of the government through the Department of Agriculture, Bureau of Fisheries and Aquatic Resources (DA-BFAR) include:

- expansion of seaweeds farming in traditional areas (currently there are 57 seaweed nurseries nation wide, using *lantay* technology in non-traditional areas);
- introduction of seaweed farming in non-traditional areas;
- adoption of appropriate technologies to increase productivity;
- conduct of research and development;
- improvement of post-harvest techniques;
- establishment of semi-processing plants in strategic areas;
- promotion of seaweed and seaweed products;
- credit facilitation/credit access;
- monitoring of seaweed price; and
- organization of seaweed farmers.

Milkfish

In line with the implementation of the Medium-Term Philippine Development Plan (MTPDP) 2005–2010 to support President Gloria Macapagal Arroyo's (PGMA) 10-point agenda, BFAR is expected to:

- Expand the present milkfish production areas by 3 190 ha. The expansion is expected to generate a total of 86 260 jobs and an annual milkfish production increment of at least 25 000 tonnes.
- Establish additional central hatcheries in strategic areas to sustain the supply of cheap but high-quality milkfish fry to fish farmers all over the country through the Philippine Bangus Development Program. The intervention is expected to help reduce the cost of fingerlings by 50 percent.
- Establish lead price including tri-media information dissemination of wholesale and farm gate prices in fish ports in order to reduce percentage of mark-up of marketing layers by 20–30 percent. The long-term goal is to eliminate marketing layers through the organization of cooperatives and provision of credit facilities.

The Philippine Bangus Development Program is a government intervention that aims to ensure the sustainable supply of milkfish fry. The programme utilizes the simple protocol of producing milkfish fry on a commercial scale. The concept includes the use of government, academic and private hatcheries as satellites. Central hatcheries will produce good-quality eggs that will be sold to the satellites for hatching and larval rearing.

Currently, there are 2 714 breeders being utilized for the programme. The central milkfish hatcheries and satellite hatcheries established nation wide are as follows:

Central Hatcheries

- BFAR-NIFTDC, Dagupan City
- BFAR-CALAPE, Bohol
- BFAR Sta. Lucia, Palawan

- BFAR-Naujan, Oriental Mindoro
- BFAR-Tiwi, Albay
- Hipolito-Damortis, Sto, Tomas, La Union
- Hautea-Dumangs, Iloilo
- Ibabao-Kalibo, Aklan
- Rivera-Cabangan, Zambales

Satellite Hatcheries
- Argao, Cebu - operational
- Bais City, Negros Occidental (operational)
- University of Northern Philippines (UNP), Sta. Maria, Ilocos Sur (operational)
- Young-Bolinao, Pangasinan (operational)
- San Felipe, Zambales (100 percent completed)
- Claveria Cagayan (launched 24 January 2006)
- Bongabon, Oriental Mindoro (under construction – 25 percent completed)

In 2005 milkfish egg production reached 195 million eggs. The recorded fry production is 9.6 million. Total clients served were 188.

Establishment of marine parks management concept of mariculture park
The objectives of this programme include:
- employment generation and poverty alleviation in the countryside;
- promotion of marine fish culture as an alternative source of livelihood for marginalized and sustenance fisher folk;
- development of an area with appropriate equipment and infrastructure that will allow fishermen, fish farmers and investors to operate cost-effectively and securely;
- development of skilled and technically capable fisher folk to support the mariculture industry; and
- promotion of the use of environmentally friendly inputs and farm management practices.

The project will be implemented at the village level wherein local government unit (LGU) participation is needed in zoning a parcel of at least 100 ha of coastal municipal water to be declared as a mariculture park. It will utilize modern floating cages that tolerate 2–3 m wave action and that will last at least five years with little maintenance.

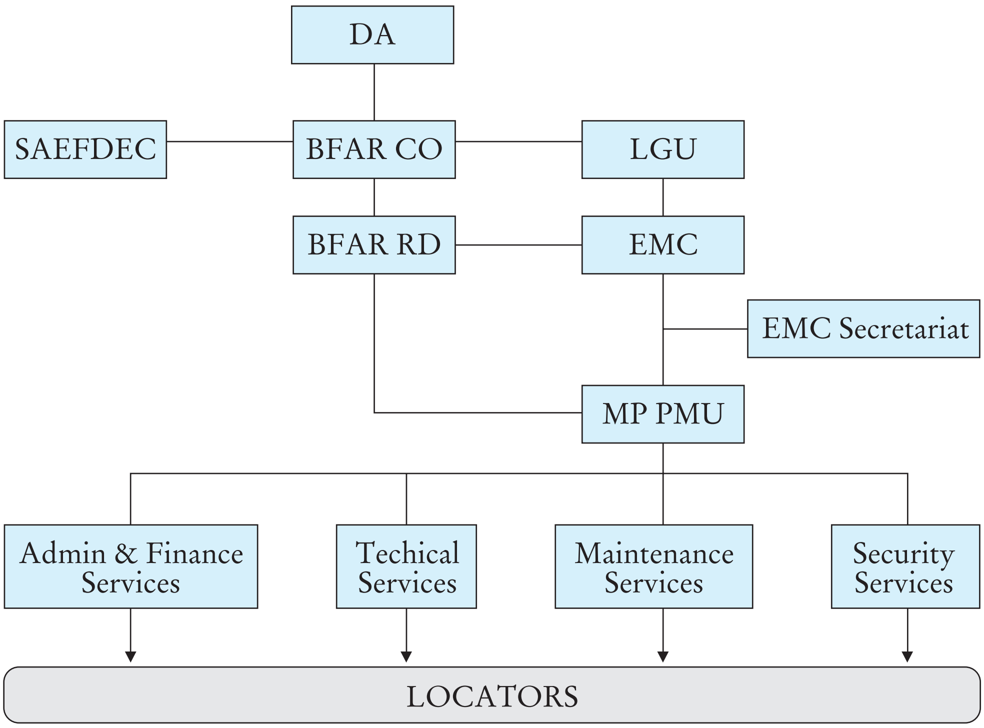
A component of the park is an Executive Management Council (EMC) that governs the establishment of a grid-type "community" storm-mooring system and cluster of marine sea-cages. Aside from providing the necessary security for the cages during seasonal rough weather, a standardized mooring facility is expected to help prevent problems of uncontrolled growth and expansion, encroachment, entanglement of moorings and navigational hazards.

The following sections describe the features and activities within different stakeholders and management units (see Figure 8).

Features
- multi-product onshore warehouse, cold storage and ice plant facility service as well as ferry boats;
- sufficient navigational lanes and a communal mooring system;
- internal and external security;
- well-defined sites for investment category for small, medium and large-scale investors;

- readily available mooring support services for small-scale operators; and
- availability of seeds and feeds supplier, cage fabricator and manpower services.

Figure 8
Organizational structure and functions[1]



[1] DA as the Executing Agency.
BFAR-SEAFDEC-LGU Signatories of the MOA.
EMC-Executive Management Committee takes charge for the over-all administration of the Marine Park Project.
BFAR-RD coordinates with the EMC on day-to-day operations.
RD as Project Management Unit (MPMU) Project Manager.
Project Management Unit (MPMU) implements the day-to-day operations of the MP.

Benefits to the LGU per hectare

- Mayor's/business permits
- PHP 1 500/mooring space/year x 30 spaces/ha = PHP 45 000
- Executive Management Council rentals
- PHP 5 000/mooring space/year x 30 spaces/ha = PHP 150 000
- employment benefits as outlined below:

Direct:
caretaker (60), security (2), maintenance (5)
Indirect:
cage fabricators (360), mooring development (15),
fry producer (133), transport and handling (5 346)

- other business/permits
- value-adding (milkfish deboning)
- cage suppliers

- feed suppliers
- fish dealers
- warehouse
- ice plant and cold storage
- milkfish hatchery operations
- milkfish nursery operations

Legal mandates

- Republic Act No. 8550
  - Section 47: Code of Practice for Aquaculture (FAO 214)
  - Section 51: License to Operate Fish Pen, Fish Cage, Fish Traps and Other Structures for Fish Culture and Other Fishery Products
  - Section 53: Grant of Privileges for Operation for Fish Pens, Cages, Corrals/Traps and Similar Structures
  - Section 54: Insurance for Fish Pond, Fish Cages and Fish Pens (FAO 215)
  - Section 55: Non-Obstruction to Navigation (FAO 216)
  - Section 56: Non-Obstruction to Defined Migratory Paths (FAO 217)
  - Section 57: Registration of Fish Hatcheries and Private Fishponds, etc. (FAO 218)

- DA-DENR Joint Memorandum Order No. 01 (series of 2000)
  - Article III, Sec. 3. Code of Practice for Aquaculture
  - Article IV, Sec. 1.a.3-4-5. Zonation of existing or potential areas for mariculture, sea farming or sea ranching operations; navigational lanes and passage in fishery areas; migration paths of migratory fishes

- Municipal Fisheries Ordinance
  - Municipal Resolution declaring, reserving or segregating an area for Mariculture Zone (in coordination and collaboration with DENR/FARMC)
  - Stipulations of fees and rentals (Mayors Permit/Annual Lease)

Development process

The development process occurs in the following sequence:

- Site selection and prioritization
- Pre-assessment of site suitability
- Public hearing/consultations
- Municipal resolution
- Municipal ordinance
- Development plan
- RRA/EIA
- Organization of EMC
- Detailed survey/ECC
- Subdivision plan
- Installation layout (mooring/cages)
- Training/IEC
- Lease/permit issuance
- Operation and management
- Regular monitoring (physico-chemical)

Technical services

Technical services for the mariculture parks are described below in Table 10.

TABLE 10
Technical assistance

Project Operations Unit	Project Assistance/Information, Education Component Unit
1. Oversee the project staff assigned at the project site 2. Implement all projects at the BFAR R&D Area Develop/implement work plan for every project Assign appropriate project staff, including on-the-job trainees Implement project monitoring and evaluation Implement researches 3. Render technical assistance to locators at different stages of project development, such as: Project installation Grow-out/culture techniques Harvesting Post-harvest activities 4. Render services as resource persons during dialogues/conferences, trainings and other related activities Provide technical back-up staff to the EMC during project deliberation and conferences	1. Recommend guidelines for the Project Operations 2. Prepare Management Plan and programme for the future development and long-term sustainability of the Mariculture Park. 3. Production of Project Operation Manual 4. Develop brochures for the whole MP 5. Develop manuscript for R&D results 6. Develop new project proposals and implement pilot models at the BFAR R&D Area 7. Provide assistance in the preparation of locators' business plan outline 8. Provide assistance to locators' documentation requirements (Mayor's Permit/lease agreement) 9. Assist with other information needs of the locators 10. Act as resource persons during community dialogues, conferences, trainings and other related activities 11. Develop IEC materials

Management and operation

- Hatchery and nursery
- Species selection
- Species selection
- Cage maintenance
- PCP-environmental impact monitoring
- Harvest and post-harvest

Status of mariculture parks

Table 11 shows the status of mariculture parks in the Philippines.

TABLE 11
Status of mariculture parks

SITE/LOCATION	STATUS	REMARKS
Samal Island Mariculture Park	Launched and established 11 August 2001 in Davao. Now on its 3rd year of operation (4 locators, 4 cooperatives and cluster of fisherfolks; 11 cages all engaged in semi-intensive polyculture system (milkfish))	LGU failed to provide parcel of land for warehouse and auxiliary service area. More locators are encouraged.
	Fully operational with BFAR Demo cages and 3 locators in full operation. BFAR techno-demo cages now contain 3 000 pompano, 2 000 snapper and 2 500 grouper fingerlings. Another 12 x 12 m cage has been set for seeding.	
	Re-established 26 mooring lines in the mariculture park.	
	Constructed and deployed 32 units (2x2) square cages owned by Coral Aqua Ventures stocked with high-value species. For recreational purposes, they planned to combine their cages with floating cottages and restaurants for the public while promoting eco-tourism in the area. Maintained 57 compartments and restocked with various high-value species like abalone, cobia, snapper and grouper.	
	Most locators harvested and restocked their cages with fingerlings. Jorona Aquaventures opted for staggered harvesting to be processed in their own processing plant.	
	Corona Aquatic Resources Trading was consistent with their fish processing activities and expansion programme. Two units of 19 x18 m cages were each stocked with 25 000 milkfish fingerlings. Other newly constructed cages were stocked with milkfish and pompano. Nine units of cages with stocks are now available, while fabrication of additional cages is on-going to meet the 30-unit targets.	
	Monteverde Aquaventures resumed its operation with one unit 10 x10 m cage ready for re-installation. Seeding has been scheduled in July 2005.	
	GE cattle Trading's three units of 10 x 10 m cages ready for seeding, while fabrication of additional units is on-going. The constructed floating house have been scheduled for installation.	
	Individual fish-cage operators and fisherfolk in the vicinity now maintain a substantial number of siganid fingerlings for the investors.	
Masinloc-Palauig, Zambales	MOU with DA-BFAR/LGUs and SEAFDEC signed January 2002. Municipal resolutions endorsed by respective Sangguniang Bayan, RRA/Profile completed. Boundaries and bouys established.	NIPAS exclusion request endorsed to DENR. Awaiting Municipal Ordinances from both municipalities and layout/ development plan prepared by Region III.
	Final copy of the Environmental Impact Statement (EIS) submitted to the EMB-DENR Central Office for review. An inventory of existing fish cage units was made on 30 March 2004 together with the current water quality assessment on the proposed site. The ECC granted to BFAR was, however, cancelled.	
Subic-Morong, Mabayo Cove	Public consultation with local officials conducted; awaiting formal endorsement to SB of Morong, Site assessment conducted by Region III.	8 locators visited the site. LGU decided to operate and manage the site on their own administration

TABLE 11
Continued

SITE/LOCATION	STATUS	REMARKS
Silangun Bay, Zambales	Survey assessment jointly conducted by BFAR-NDCP team, MOA formally signed between AFP-NDCP and DA-BFAR last 13 February	Implementation/development plan prepared. Detailed RRA conducted jointly by BFAR-Philippine Navy and NDCP. Operation and management to be privately administered by a corporation.
Honda Bay, Palawan	Site to be identified by Reg. IV	For implementation
Ragay Bay, Camarines Sur	Survey assessment jointly conducted by BFAR-LGU team. Profile and development plan prepared by the LGU.	For implementation
Sto. Tomas Cove, La Union	Launched and established 17 October 2002 in St. Tomas, La Union	27 investors were awarded with Mariculture Zone Economic Agreement.
Region 1	Assessed 16 sites for proposed seaweed mariculture zones in the four provinces of Region 1.	
	Established seven seaweed mariculture zones in Pasuquin and Badoc, Ilocos Norte; Cabugao, Santiago and San Esteban, Ilocos Sur; Dasol and Balaoan Pangasinan.	
Tilik Cove, Lubang Island	Survey assessment jointly conducted by BFAR-LGU team 20 October 2003	Ordinance drafted by LGU. Limited sites suitable for Mariculture Project.
SEAFDEC-AQD Igang, Guimaras Sub-province	Mariculture Park Pilot-Demo and Training Project fully operational	JMANTTP Prototype Mariculture Park
Samar-Leyte	Existing Mariparks established in Leyte as of 2004	8 Mariculture Zone Established
	2 new areas proposed in Biliran and Tacloban	42 units of cages installed
	3 existing Mariparks established in Samar	Production of 2005: 255 tonnes
	2 proposed new sites in Quinapondan and Marabut, Samar	Average production/unit 7.5–8 tonnes
Malajog, Calbayog Nothern Samar and Basey Eastern Samar	11 BFAR demo cages (9 units square and 2 units circular) maintained at the mariculture parks located. 47 cages (32 square GI pipes, 4 units circular and 11 units square) installed by investors while regular technical assistance was provided by BFAR.	

Mariculture Park Region VIII

Existing

- Malajog,Calbayog Nothern Samar (300 ha)
- Basey Eastern Samar (400 ha)
- Merida, Leyte
- Ormoc Bay, Northern Leyte (600 ha, launched 7 December 2005)
- Ormoc/ Merida Mariculture Zone (100 ha)
- Babatngon, Leyte (950 ha, launched 27 December 2004)
- Sta Rita, Mariculture Park, Western Samar (500 ha)
- Liloan, Sagud Bay, Southern Leyte (75 ha, launched 30 July 2004)
- San Jose City, Northern Samar (3 150 ha, launched 30 June 2004)
- Lawaan, Eastern Samar (launched 4 August 2004)

Proposed

- Biliran/Leyte, Leyte
- Quinapondan Mariculture Zone, Eastern Samar
- Marabut
- Tacloban, Leyte

Sea cages

- Established 8 mariculture zones
- No. of established cages: 142 units
- Production as of 2004: 255 tonnes
- Average production/unit: 7.5–8 tonnes

Challenges and opportunities

The challenges and opportunities for mariculture parks include the following:

Macro-scale benefits

- Food security
- Employment generation
- Long-term sustainability

Micro-scale benefits

- Ancillary services (seed stocks, ice-plant, cold storage, feed warehouses, ports, etc.)
- Post-harvest facilities, road and transport access
- Lesser investment cost
- Amenities (water supply, power supply, communications, guard house, working platforms)
- Full security
- Revenue assurance to LGUs

Other opportunities

- Tax incentives (ITH)
- Crop insurance
- Choice of commercially important species
- Market assurance
- Fish health management services
- ISO/HACCP standards
- Programmatic compliance to DENR (EIA/EIS/ECC)
- Other livelihood opportunities

Environmental issues

Over the last few years, the rapid development of marine fish-cage and fish-pen culture in certain areas of the Philippines has led to unsustainable production. In 2002 for example, fishkills occurred in milkfish culture areas in Pangasinan and in tilapia areas in Taal Lake. Possible reasons for these fishkills are: euthrophication, over production, overstocking of cages and pens, toxic algal tide or algal bloom, poor production management and reduction of water refreshment due to poor zoning and regulation.

In 2005 a study on Environmental Monitoring and Modelling of Aquaculture Areas was conducted. The primary objective was to undertake an environmental survey of the risk areas and adapt a mathematical model based on MOM Standard (Modeling–Ongrowing fish farms-Monitoring) developed by Norway for the prediction of impact of the fish cages on the recipient water. The study was implemented in collaboration with AKVAPLAN NIVA and the Norwegian Agency for Cooperation and Development (NORAD).

The survey was conducted in Bolinao marine waters, Dagupan City River system and Taal Lake during summer, rainy and cold seasons. The following activities were conducted:

- detailed survey of production in the area (including physical area, production, statistics etc);
- analysis of the bathymetry;
- profiling of temperature, salinity and oxygen levels through the water;
- sediment analysis;
- survey of current speed and direction;
- recording of tidal range observations; and
- monitoring of wind direction, frequency and speed.

Initial results of the survey in Bolinao showed that there are 460 fishcages, 266 fishpens and 254 mussel farms. Soil samples taken by grabs are grey to black in colour and with a hydrogen sulphide (H_2S) smell.

Results of the survey in Dagupan showed that there are 124 fishcages, 553 fishpens, 528 fish traps and 94 oyster farms. Soil samples taken by grabs have no smell, with greyish silty sediment. Oysters were found to abound in the river.

The initial findings were:

- food conversion rate was varied and was relatively poor (1.5 to 3:1);
- impact was relatively high in areas where there are large numbers of fishcages;
- impact was relatively low in areas where there is a mix of fish and mollusc culture (fed species and extractive species);
- carrying capacity was not related to numbers of structures but to fish production; and
- carrying capacity varied through the year depending on other factors (dynamic)

The initial recommendations were to come up with constructive and implementable recommendations that allow efficient production and minimize impact. An example is the use of feeding trays. In this way a farmer has better food conversion rate (more fish per kilogram of feed) and there is less impact on the environment (reduction of nutrients and organic material released to the environment).

CONCLUSIONS

With the increasing population, the government has to choose between food security/ sustainability and environmental protection/conservation. The government has to decide which areas to regulate for mariculture and which areas to allow open access to fish farming.

Another issue to consider is zonation vs. degradation. Mariculture areas should be identified but properly regulated to prevent degradation of the rivers and seas.

Government policies/regulations have to be put in place to prevent environmental degradation, thereby sustaining production. Research and development should focus in determining the carrying capacity of water. The Local Government Units (LGUs) should ensure that their fishery ordinances are strictly enforced, giving emphasis to the interest of the less fortunate fish farmers.

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Thailand

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BACKGROUND

Thailand has a coastline of 2 769 km, of which 1 875 km is facing the Gulf of Thailand from Trad to Narathiwat Province, and the remaining 894 km faces the Andaman Sea from Satul to Trang Province. Coastal and marine aquaculture in Thailand has a long history that dates back to when mass seed production from hatcheries first succeeded in raising marine shrimp (banana shrimp, *Penaeus merguiensis* and black tiger shrimp, *P. monodon*) and Asian seabass (*Lates calcarifer*) around 1969 to 1976. Coastal and marine aquaculture has developed under the administration of the Ministry of Agriculture, Department of Fisheries (DOF). The Coastal Fisheries Research and Development Bureau has 19 Coastal Fisheries Research and Development Centers (CFRDC) and three Coastal Aquaculture Research and Development Stations. Provincial Fisheries Offices (PFO) in 24 coastal provinces also have the duty of supporting development of coastal aquaculture and enforcing the fisheries laws and regulations. The national fisheries development policies on aquaculture development are as follows:

- increase aquaculture production sufficiently in both quantity and quality for domestic consumption and export;
- accelerate research in support of commercial aquaculture industries to increase trade volume, improve quality standards and reduce production costs;
- develop sustainable marine shrimp culture systems for domestic trade as well as for export; and
- develop the production and marketing of ornamental fish and aquatic plants for export in order to raise the income from aquaculture.

MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKETS

Analysis of marine aquaculture products demand, trade and markets trend in Thailand

Demand for export, product demand, trade and markets

The foreign trade in fisheries commodities was 1 647 866 tonnes by quantity and more than US$4 377 million by value in 2003. The major exports are fresh chilled and frozen marine shrimps (118 913 tonnes) and fishes (377 736 tonnes) and their products. Marine shrimps (chilled or frozen) were exported mainly to the United States of America (62 861 tonnes) and Japan (22 363 tonnes). Marine fishes were exported to Malaysia (133 791 tonnes), Japan (105 088 tonnes), the People's Republic of China (28 464 tonnes), Singapore (20 397 tonnes), Taiwan Province of China (13 194 tonnes) and the Republic of Korea (11 317 tonnes) (CITC, 2003). Italy imported 27 723 tonnes of fresh chilled or frozen squids. Tuna is the major fish exported with >326 402 tonnes both packed in air-tight and non-air tight containers in 2003, mainly for the United States of America, Australia, Canada, Japan and the United Kingdom (see Appendix I).

Thailand imported products of more than US$1 162.8 million in value and 1 095 059 tonnes in quantity in 2003, mostly fresh chilled or frozen fish (>950 000 tonnes) (Table 1) from Indonesia, Japan, Taiwan Province of China, Republic of Korea, China and the United States of America. The other major imported seafoods were fresh, frozen or salted molluscs from Malaysia (18 255 tonnes) and shrimps in non-air tight containers from Indonesia and Malaysia (3 276 and 1 536 tonnes, respectively).

Marine aquaculture for domestic markets

The main species supplied for the domestic market are finfish, some small shrimps and mussel. Marine fishes are sent by truck or car to northern Thailand. Shrimp, fish and molluscs from farm sites along the coastline are always transported as fresh chilled or frozen products to Bangkok and other local destinations within one or two days. Goods will be sent directly to the market and to distributors who will use small cold storage or ice boxes. Live fish and molluscs are preferred by restaurants. Food safety standards are being applied.

TABLE 1
Quantity of imported seafood by selected country and commodity, 2003 (tonnes)

Country of Origin	Total	Live	Fresh chilled or frozen			
		Fish	Fish	Shrimp	Crab	Squid
Australia	10 444	-	1 042	172	-	-
Canada	6 528	-	1 907	1 847	2 433	-
China	24 696	1	17 598	1 522	53	432
EU	16 252	-	13 325	648	249	379
Indonesia	262 861	4	252 436	1 529	-	4 367
India	11 364	-	5 730	4 304	23	1 169
Japan	107 423	5	100 007	309	63	1 219
Malaysia	34 525	31	6 645	2 403	14	654
Philippines	3 384	2	3 290	10	-	6
Republic of Korea	40 536	-	30 368	151	72	1 178
Singapore	1 109	1	963	-	-	-
Taiwan PC	123 124	1	122 026	11	-	281
USA	20 667	-	14 573	218	265	-
Viet Nam	10 145	-	2 679	1 440	43	2 164
Others	422 272	4	38 2533	11 960	2 399	12 937
Total	1 095 059	49	955 122	26 524	5 614	24 777

Role of aquaculture versus fisheries

Data from the 13-year period since 1993 show that capture fisheries tended to decline, while the culture production has increased and only declined again in 2005 (Figures 1 and 2). The average supply was 73.1 percent from marine capture and 14.2 percent from mariculture, clearly indicating that the main supplies of seafood were from capture fisheries rather than culture. The majority of coastal aquaculture is shrimp, fish and mollusc farming. Their production and the number of farms are shown in Figures 3 and 4.

In 2003 there were 34 977 shrimp farms with a total pond area of 512 620 rai (82 019.2 ha; 1 rai =1 600 m^2), with a total yield of 330 725 tonnes. Production was 194 909 tonnes of black tiger shrimp, 132 365 tonnes of white shrimp, 2 849 tonnes of banana shrimp and 602 tonnes of other shrimp.

For finfish culture, there were 8 226 farms, out of which there were 1 073 pond operators and 7 153 cage operators with a total area of 6 625 rai (1 019.23 ha, 1 ha = 6.5 rai), with a total yield of 14 568 tonnes, of which 12 229 tonnes were seabass and 2 339 tonnes were groupers. The total yield of pond culture was 3 456 tonnes, of which 3 102 tonnes were seabass and 354 tonnes were groupers. The total yield from cage culture was 11 112 tonnes, of which 9 127 tonnes were seabass and 1 985 tonnes were groupers.

For mollusc culture, there were 5 935 farms with a total area of 75 888 rai (11 676 ha), of which 73.8 percent of the area was for blood cockle, 17.8 percent for green mussel and 8.4 percent for oyster. Total yield was 357 944 tonnes, with 67 359 tonnes from blood cockle, 263 946 tonnes from green mussel and 26 639 tonnes from oysters (FITC, 2003).

Figure 1
Aquaculture vs capture fisheries from 1993 to 2005 in Thailand
(estimates for 2004 and 2005)

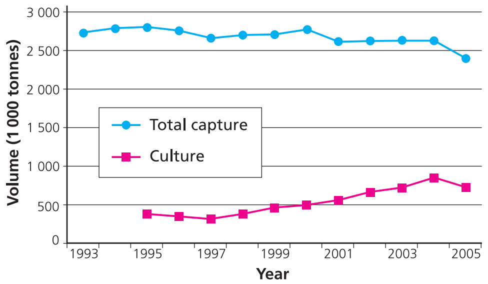


Figure 2
Total production declined in year 2005

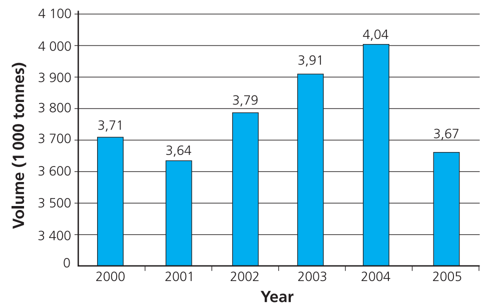


Figure 3
Number of coastal aquaculture farms, 2000–2005

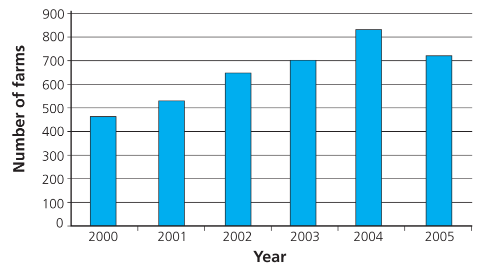
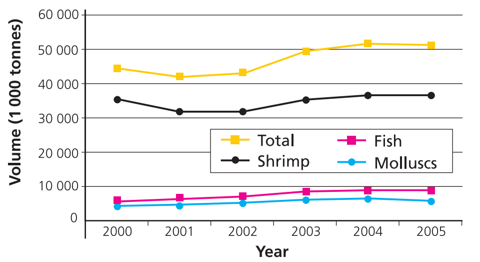


Figure 4
Annual production from coastal aquaculture, 2000–2005



2.3 Consumer trends, preferences, buying patterns

Analysis from Thailand's two major markets, Japan and the United States of America, reveals different preferences and products, as shown in Table 2.

TABLE 2
Buyer preferences – analysis for two major clients of Thailand's marine products, Japan and the United States of America (tonnes) (Source: modified from FITC, 2003)

Product	Japan			USA		
	Fishes	Shrimps	Others	Fishes	Shrimps	Others
Fresh chilled or frozen	105 088	22 363	31 323 (squids)	10 132	62 861	5 711 (squids)
Packed in air-tight container	15 743 (tuna) 116 (sardine)	522	65 871 (others) 171 (crabs) 142 (asari)	83 839 (tuna) 3 768 (sardine)	3 734	15 267 (others) 4 633 (crabs) 2 642 (asari)
Packed in non-air tight container	8 339 (tuna) 6 (sardine)	22 892	7 500 (squids) 991 (crabs) 331 (asari)	24 222 (tuna) 33 (sardine)	65 568	159 (squids) 92 (crabs) 25 (asari)
Prepared or preserved	28 714	-	2 638 (others)	11 902	-	2 251 (others)
Total	158 006 24 082 (tuna) 122 (sardine)	45 777	68 509 (others) 38 832 (squids) 1 162 (crabs) 473 (asari)	133 896 108 061 (tuna) 3 801 (sardine)	132 163	17 518 (others) 5 870 (squids) 4 725 (crabs) 2 667 (asari)

Market chain organization, market trends and vulnerability

The seafood market chains in Thailand are divided into many channels for shrimp, fish and other aquatic animals. The market chain for marine shrimp is rather complicated, involving hatcheries, nurseries, grow-out farms and harvest/partial harvest, with sales to domestic markets and cold stores, and processing for export. Thailand has developed standards for hatcheries, nurseries and farms under a Good Aquaculture Practice (GAP) and Code of Conduct (COC) programme. There are 24 Raw Materials Inspection Units for coastal shrimp farms for checking quality, diseases and antibiotic residues of shrimp. Aside from fresh chilled products and products frozen in many ways, shrimp are also processed in steamed, cooked and precooked forms in different packages or containers. Factories as well as cold storages are also operated under international standards to ensure safety and quality of products.

Market chains for fish and molluscs are more common than for shrimp. Most of the finfish are from capture fisheries. The chain starts from the fishermen to the fish landing, then to middlemen or collectors, who place the product in cold storage or in ice boxes to distribute to the market, and then to consumers or exporters. For cultured finfish, farmers will sell their products to a wholesaler via middlemen or direct, then distribute to consumers via sellers in the market or to exporters.

For molluscs, harvests will be transported to markets, either via distributors or directly, or to exporters. Some will be processed and then repacked and sold.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

Information on coastal communities, poverty status, livelihoods, trends and vulnerability, and identification of key target communities

Coastal communities comprise fishermen and their families. The main operations are small-scale fisheries and aquaculture (gill netting, net-cage culture; blood cockle, mussel and oyster culture; aquatic animal collection, etc.). Farming of marine fish is connected to the wild capture fishery, as fishers collect fish from their traps/fishing gear for use as seed and feed. Survey results from the National Statistic Office and DOF on small fishery households (SFH) in fisheries show a total of 50 732 households, of which the Province of Songkhla had the biggest number (6 175 households) followed by Krabi, Phang-nga and Nakhon Si Thamarat. The top income of SFH was from Samut Prakan Province, with US$4 736[1], and the lowest income was from Samut Songkhram with US$1 829 per household per year (Table 3).

Songkhla Lake fisheries communities in Songhkla, southern Thailand provide an example of good aquaculture and fisheries management, with cage culture of seabass, small-scale shrimp culture, culture of green mussel and small fishing boats all operating. Technical cooperation and services to promote Good Aquaculture Practice (GAP) by the National Institute of Coastal Aquaculture (NICA), the Institute of Coastal Aquatic Health Research (ICAHR) and the Provincial Fisheries Officer (PFO) have helped this development. Coastal Fisheries Patrols are also assigned to enforce laws and regulations in Songkhla Lake.

According to Boonchuwong and Lawapong (1999), on average each marine fishfarmer in the Andaman sea coast of southern Thailand owns four cages (4x4x4 m^3 each). The average production is 210 kg/cage (175 fish), with a size range from 1.0–1.2 kg from a culture period of 9–12 months. The production cost is US$3.5/kg, of which 75 percent is feed cost. Most farmers start to harvest fish after nine months of culture at a selling price of US$7.3 /kg.

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1 Calculated from Table 3 using an exchange rate of US$1 = 40 baht (B).

TABLE 3
Average annual income for small households in fisheries commodities by province (Source: Office of National Statistics and Department of Fisheries, 2000)

Province	Total income (B)	Capture fisheries	Aquaculture	Processing	Non-fisheries income
Trat	106 017	87 463	3 107	525	14 922
Chanthaburi	96 410	84 933	604	773	10 100
Rayong	102 195	75 484	1 122	563	25 026
Chonburi	140 864	122 428	2 391	1 344	14 701
Chachoengsao	133 283	87 159	14 274	27 566	4 284
Samut Prakan	189 454	164 132	4 107	96	21 119
Samut Sakhon	171 754	102 335	2 234	19 164	48 021
Samut Songkhram	73 179	59 533	-	833	12 813
Petchaburi	100 061	91 425	22	65	8 549
Prajoub Kiri Khan	135 223	119 938	-	-	15 285
Chumphon	155 001	128 018	1 473	4 789	20 721
Surat Thani	86 274	70 778	-	2 787	12 709
Nakhon Si Thamarat	94 912	86 482	339	22	8 069
Songkhla	76 811	52 598	1 906	1 776	20 531
Pattani	96 277	89 426	-	-	6 851
Narathiwat	78 570	67 342	33	1	11 194
Ranong	92 627	77 039	318	2 857	12 413
Phang-nga	76 686	66 821	39	775	9 051
Phuket	103 987	72 121	203	407	31 256
Krabi	74 786	54 974	-	1 523	18 289
Trang	68 428	54 561	-	154	13 713
Satul	74 516	65 487	2 181	36	6 812
Total	2 327 315	1 880 477	34 353	66 056	346 429

Markets and coastal community development linkages

Development of coastal communities is necessary for sustainable management of coastal fisheries and aquaculture. Suitable roles for women in coastal fisheries and aquaculture are very important. The harvest in some seasons provides an over supply to local markets, and women get involved in preservation and preparation of products such as shrimp paste, dried fish and mussel and fish sauce. The PFO in every coastal province is also active in providing training on preservation and fisheries products.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Technology for mariculture had been transferred in Thailand through many channels. These include via discussions and meetings in small groups or seminars that can be done at any time at the CFRDC of DOF in coastal provinces. DOF then provides training that is divided into (i) training for trainers, technicians and fisheries officers, in order to be good trainers; and (ii) training for farmers and other stakeholders through lectures, workshops, demonstrations and practicals in laboratory or on farm, including study tours to view activities at other sites.

The DOF also has a website (www.fisheries.go.th) for information dissemination. Every PFO and CFRDC can have its own website where farmers and other interested stakeholders can gain knowledge and ask questions.

Present training activities and likely future requirements

Training
Annually 25 000 farmers and other interested parties are trained through training courses for fisheries technology and fish farming. These courses include basic techniques and practical methods for aquaculture, including inland aquaculture. The typical training curriculum includes:

- culturing of economically important fishes including ornamental fishes, pond culture, cage culture, etc.
- breeding and nursing of aquatics species;
- homemade formulated diet for fish culture;
- diseases and prophylactic measures; and
- preserving and processing of aquatic species.

Aside from such training courses, DOF sets up demonstration sites in selected fisheries communities and assists with mobile clinics, which includes technical assistance to farmers to help solve their problems, water analysis, disease diagnostics, etc.

Training for technicians and government officers through training of trainer programmes is provided to update the knowledge of officers and technicians (trainers). Special emphasis in recent years has been on training in GAP, COC and other measures.

Seminars
Special seminars are provided on the breeding and culture of selected aquatic animals, such as Babylon snail and of selected groupers and clown fishes.

Food safety for fisheries production programme
This programme was set up to promote clean seafood and its production for domestic markets and export. Many training programmes with this concept have been conducted to train government officers, farmers and other stakeholders.

Developing information technology
IT for fisheries is needed to provide up-to-date information and for compilation and dissemination of relevant information to farmers and the general public.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Coastal aquaculture in Thailand involves the culture of shrimp, fish, shellfish and small quantities of other aquatic animals.

Status of farming of selected species

Marine finfish farming in Thailand began four or five decades ago. The two predominant species groups are groupers and seabass, which are cultured in both earthern ponds and coastal cages. Most of the seabass farms are located in estuarine areas, but almost all groupers are cultured in cages located in more marine waters. Bays or coastal enclosed areas protected from wave action and strong winds are preferred.

Grouper culture has proved to be commercially viable, depending on the export market in the region. The price for live fish weighing 1.2–1.5 kg has been US$9–10 each or US$7–8/kg since the 1990s, with limited long-term price fluctuations. Most fishfarmers culture grouper in floating netcages in sheltered coastal areas with salinity ranging from 12 to 30 ppt.

Due to unreliable and limited hatchery production, the majority of grouper seed are obtained from the wild. Grouper fry of size 1.0–2.5 cm are usually collected from the coastal areas of Songkhla and Pattani provinces from October to March. The fry are reared up to a size of 7–10 cm prior to stocking in grow-out cages. The majority of these seed are exported to other countries. Seed of sizes longer than 10 cm are collected using traps, and the fish are stocked directly into grow-out cages without nursing. Fishfarmers prefer this type of seed to the reared fry because of the shorter grow-out period and better survival. The quantity of fish produced from cage culture is steadily increasing and its future appears to be promising.

The grouper culture system involves a series of farms specialized in one of several areas:

- Hatcheries produce fertilized eggs
  - broodstock ponds (outdoor)
  - induced spawning
  - natural spawning
- Fertilized eggs → fry farm
  - nursing indoor (raise to 3 cm total length)
  - nursing outdoor
- Fingerling farms → until 7–9 cm total length
- Grow-out farm → market size (600–700 g)
  - pond culture (10–14 months)
  - cage culture (8–10 months from 6 cm)

Fry and fingerling production

The demand for live marine finfish such as groupers and seabass for consumption has increased. To produce marine fish seed, we have to understand the reproductive biology and physiology of each species.

TABLE 4
Production yields from grouper culture and their food used, in weight (tonnes), 1999–2002

Year	Seabass/Feed		Groupers/Feed		Total feed used
	Weight	FCR=7.5	Weight	FCR=5.5	
1999	6 056	54 120	1 143	7 339	61 459
2000	7 752	70 040	1 312	8 299	78 339
2001	8 003	72 750	1 443	9 507	82 257
2002	11 032	105 100	1 170	7 794	112 894

The use of destructive fishing methods has destroyed the habitats on which reef-associated species such as groupers depend for shelter and food. The requirements needed to assist the development of marine finfish culture are as follows:

- efficient live feed production in the hatchery/nursery;
- steady supply of live feeds for commercial-scale culture of difficult species;
- strong government support for the industry and research;
- seed supply centers in the country and region;
- good cooperation between fisheries organizations, information networks, market chains and research laboratories (fisheries institution/university integration); and
- continuation of government policies/plans for hatchery-reared seed to restock over-exploited coastal fisheries.

Hatcheries that produce groupers are the five main government hatcheries and two private hatcheries in Rayong Province. The government hatcheries, with names of key R&D species, are listed below:

Southern region

- National Institute of Coastal Aquaculture (NICA), Songkhla Province
  Epinephelus coioides, *E. malabaricus*

- Krabi Coastal Fisheries Research and Development Center, Krabi
  E. coioides, *E. lanceolatus*, *E. fuscoguttatus*
- Satul CFRDC, Satul
  E. coioides, *E. malabaricus*

Eastern region
- Rayong CFRDC, Rayong Province
  Cromileptes altivelis
- Trat Coastal Aquaculture Station, Trat Province
  Plectropomus leopardus

Cobia (*Rachycentron canadum*) has been produced at Phuket and Satul CFRDC since 2004, and at Rayong CFRDC in 2005.

Future prospects for finfish research and development (R&D) include:
- developing closed recirculation systems for fish hatcheries and nurseries;
- providing education and training on marine fish farming; and
- organizing an enhanced network for cooperation among fish culturists (the whole cycle) using IT.

Priorities for research and development

R&D for shrimp, finfish and molluscs should be on:
- developing suitable feeds for each species (and each life stage);
- changing traditional destructive culture methods, such as feeding with small fresh fish by training fishfarmers to use formulated feeds, and other means to make the transition to formulated feeds;
- improving disease prevention and prophylactic measures;
- enhancing the capacity and awareness of all aquatic farms to follow GAP and later, to practice more comprehensive environmentally friendly farming under the Code of Conduct (COC) in order to have sustainable aquaculture in Thailand and the region.

Identification of better management practices (BMPs) for existing farmed species and systems to mitigate environmental impacts

Freshwater runoff is the major cause of impacts on mariculture in Thailand. The DOF has been active with a GAP and COC for all shrimp farming areas since 2003. These programmes should also be applied to other aquatic animal farming systems. The COC, in particular, will mitigate environmental impacts as a result of applying environmentally friendly practices. Laws and regulations protecting the environment also need strengthening. Youth are more aware of the environment and the need for better environmental management and should be involved in educational and awareness programmes to enhance the environmentally sustainable development of aquaculture.

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APPENDIX I

Quantity of exports by country and commodity from Thailand in 2003 in tonnes (Source: CITC, 2003)

Country of destination	Total	Aquatic live animal		Fresh, chilled or frozen					Steamed, boiled, salted, dried or smoked				Fresh, frozen and salted	
		Fish	Other	Fish	Shrimp	Crab	Squid	Other	Fish	Shrimp	Crab	Squid	Mollusc	Others
Australia	78 308	18	-	2 099	4 034	16	4 761	195	-	-	-	-	-	-
Belgium	4 233	15	-	1 409	140	-	338	9	-	-	-	-	-	-
Canada	47 745	31	-	655	6 690	45	1 981	-	-	-	-	-	-	-
China	40 134	174	389	28 464	2 781	2	4 009	7	-	-	-	-	-	-
Germany	17 862	61	-	1 253	182	3	1 176	9	-	-	-	-	-	-
Denmark	5 059	3	-	43	1	-	276	-	-	-	-	-	-	-
Spain	9 264	24	-	1 274	29	3	2 443	-	-	-	-	-	-	-
Finland	4 861	1	-	-	-	-	-	-	-	-	-	-	-	-
France	16 093	24	-	2 509	88	80	2 397	-	-	-	-	-	-	-
UK	32 045	24	1	1 080	132	5	660	-	-	-	-	-	-	-
Indonesia	9 571	3	-	639	143	-	-	-	5 319	-	-	-	3	3
Italy	39967	16	-	1 831	74	10	27 723	12	-	-	-	-	-	-
Japan	370 851	61	-	105 088	22 363	544	31 323	10	-	-	-	-	-	-
Korea Rep.	30 692	26	58	11 317	6 430	277	1 221	10	-	-	-	-	-	-
Malaysia	170 005	71	3	133 791	250	224	643	-	16 376	3	14		1	427
Netherlands	9 947	24	-	858	49	-	367	1	-	-	-	-	-	-
Philippines	7 030	16	-	1 368	-	-	-	-	-	-	-	-	-	-
Sweden	6 051	4	-	74	3	-	1	-	-	-	-	-	-	-
Singapore	40 903	250	1	20 397	4 921	83	797	-	-	-	-	-	-	-
Taiwan PC	51 599	248	76	13 194	2 600	977	5 712	16	3 883	-	2	4	953	293
USA	320 648	615	4	10 132	62 861	833	5 711	501	-	-	-	-	-	-
Viet Nam	3 799	10	43	607	142	20	14	-	-	-	-	-	-	-
Others	331 199	4 114	1 923	39 654	5 000	994	6 208	40	22 931	461	84	1 928	14 515	8 912
Total	1 647 866	5 833	2 498	377 736	118 913	4 116	97 761	810	48 509	464	100	1 932	15 472	9 635

Quantity of exports by country and commodity from Thailand in 2003 in tonnes (Source: CITC, 2003)

	In airtight containers							Not in airtight containers						Prepared or preserved			
	Sardine	Tuna	Other	Shrimp	Crab	Squid	Asari	Sardine	Tuna	Shrimp	Crab	Squid	Asari	Fish	Shrimp	Crab	Other
Australia	1 420	26 626	7 632	202	207	1	32	6	1 980	3 614	-	48	341	4 481	-	-	565
Belgium	-	-	-					-	-	-	-	-	-	-	-	-	-
Canada	429	23 660	137	263	422	1	1 443	-	1 627	7 215	1	69	-	-	-	-	-
China	-	-	-					-	-	-	-	-	-	-	-	-	-
Germany	34	9 081	515	15	4		70	-	-	-	-	-	-	-	-	-	-
Denmark	-	-	-					-	-	-	-	-	-	-	-	-	-
Spain	-	-	-					-	-	-	-	-	-	4 200	-	-	-
Finland	132	4 218	248					-	-	-	-	-	-	-	-	-	-
France	-	-	-					-	3 435	-	-	-	-	-	-	-	-
United Kingdom	173	14 689	1 307	209	332		148	-	-	772	-	9	1	6 766	-	-	132
Indonesia	-	-	-					-	-	-	-	-	-	-	-	-	-
Italy	-	-	-					-	2 828	3	7	987	31	-	-	-	-
Japan	116	15 743	65 871	522	171		142	6	8 339	22 892	991	7 500	331	28 714	-	-	2 638
Korea Rep.		-	-					-	-	-	-	-	-	-	-	-	-
Malaysia	4 193	1 956	616		2		1	-	-	-	-	-	-	3 899	-	-	115
Netherlands	426	2 806	145	117	35	219	7	-	-	-	-	-	-	-	-	-	-
Philippines		-	-					-	-	-	-	-	-	-	-	-	-
Sweden		4 068	596	25	113			-	-	-	-	-	-	-	-	-	-
Singapore	2 205	1 631	761	3	29		22	-	-	-	-	-	-	5 615	-	-	81
Taiwan PC	28	1 706	1 355	-	1		3	-	-	-	-	-	-	-	-	-	-
USA	3 768	83 839	15 267	3 734	4 633	16	2 642	33	24 222	65 568	92	159	25	11 902	-	-	2 251
Viet Nam	-	-	-		-			-	-	-	-	-	-	-	-	-	-
Others	30 841	136 379	7 071	1 346	1 956	844	202	2 039	26 595	8 215	22	1 285	168	49 026	9	-	3 028
Total	43 765	326 402	101 521	6 436	7 905	1 081	4 712	2 084	69 026	108 279	1 113	10 057	897	114 603	9	-	8 810

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BACKGROUND

Viet Nam has more than 3 200 km of coastline with many bays and coastal areas, and thus thousands of hectares of brackish and marine areas with favourable natural conditions that are suitable for mariculture development. However, mariculture in Viet Nam has only developed within the past few years. The Vietnamese government has plans for the future development of mariculture and hopes to reach the target of 200 000 tonnes of farmed marine fishes by the year 2010.

Mariculture in Viet Nam's national economy

After only a few years of development, Viet Nam has become one of the top shrimp-producing countries in the world. In 2005 total production of fisheries in Viet Nam was 3 432 million tonnes, including:

- 1 437 million tonnes of aquaculture production;
- 330 000 tonnes of shrimp;
- 400 000 tonnes of catfish;
- 22 289 tonnes of crab;
- 114 570 tonnes of molluscs; and
- 20 257 tonnes of seaweeds.

With its favourable potential, including natural conditions, Viet Nam wishes to develop mariculture and to elevate it to an important sector that contributes to economic development, creating jobs, assisting in poverty alleviation and increasing living standards for the people.

The domestic market in Viet Nam has great potential for the consumption of marine fisheries products because shrimp, fish and molluscs are preferred foods. In the Vietnamese diet, 40–50 percent of the daily protein consumption comes from aquatic products. Marine fishes are preferred to freshwater fishes because of their value. With a population of more than 80 million people and living standards increasing day by day, Viet Nam has a high and growing demand for seafood. Cities and industrial zones are growing or forming, which creates local markets for seafood consumption. Like the Japanese and Chinese, the Vietnamese people prefer live seafood, which mostly comes only from aquaculture. Furthermore, Viet Nam is near markets in China, Hong Kong SAR and the southwestern part of the People's Republic of China. In recent years, ten tonnes of mariculture products, such as groupers, clams and lobsters have been sold daily in these markets.

With nearly 30 coastal provinces and half of the Vietnamese population living in coastal areas, mariculture plays an important role in poverty reduction. From the end of the twentieth century, the Government of Viet Nam has had policies to reduce fishing, especially in coastal areas. Over the last five years, marine fishery production has only increased slightly, mainly from offshore fishing. The government has issued policies to support the shift of fishermen from fishing to aquaculture. These policies have promoted the important role of mariculture in Viet Nam's economy. Although mariculture has just developed within the last three to four years, the Ministry of Fisheries of Viet Nam has carried out its master plan for sustainable development as a guideline for local authorities to plan detailed aquaculture areas and issue their own policies to increase the development of mariculture. The Government of Viet Nam hopes to reach a target of 200 000 tonnes of marine fishes from mariculture by the year 2010 through its specific policies and methods.

CURRENT STATUS OF MARICULTURE IN VIET NAM

Seed production

Viet Nam began research on fish reproduction in 1996–1997. As of 2005, the following fish species have been reproduced:

Orange-spotted grouper (Epinephelus coioides)

Currently, the Research Institute of Aquaculture No. 1 (RIA 1) can reproduce orange-spotted grouper with a 13–15 percent survival rate from larvae to fry (4–5 cm in length) over 60 days. The survival to 90 days (8–10 cm length) is 8–9 percent. Every year, with its facilities, RIA 1 can produce some 400 000–500 000 fry. This technology has been transferred to local areas in order to meet the demand of commercial mariculture.

Cobia (Rachycentron canadum)

Rachycentron canadum is a species for mariculture with high commercial value. Currently, Viet Nam is one of a few countries that have successfully researched and established the breeding technology and commercial farming of this species. The species has very favourable breeding characteristics; the maturation rate of captive broodstock is about 65–78 percent; the spawning rate is more than 70 percent, the egg fertilization rate more than 60 percent, the hatching rate of eggs more than 70 percent; and survival rate from larvae to fingerling (5–6 cm in length) is on average 5 percent. In 2005 the survival rate had been increased to 15–20 percent. The technology has been transferred by RIA 1 to some private hatcheries. Over the past three years, RIA 1 has produced 250 000–400 000 fry (5–6 cm) per year for marine fish farms.

Red drum (Scaenops ocellatus)

In 2003 artificial seed reproduction technology for red drum became well established. The maturation rate of broodstock is more than 72 percent, the egg fertilization rate is more than 75 percent, the egg hatching rate more than 80 percent; and the survival rate from larvae to 60-day fry more than 22 percent. In 2003, approximately 350 000 fry were produced, a figure that increased to 400 000 in 2004 and to 500 000 in 2005. The technology can be transferred to private hatcheries to increase the number of fry.

Seabass (Lates calcarifer) *and Waigieu seaperch* (Psammoperca waigiensis)

RIA II and the University of Fisheries have successfully researched this technology. Now RIA I can manage this technology and transfer it to hatcheries. In 2005, research stations produced more than 400 000 fry (3–4 cm in length) to supply fish farms.

Molluscs, crabs and other species

Viet Nam has conducted successful research on the artificial seed production of mud crab, swimming crab, sea urchin and *Babylonia* snail, as summarized below (Table 1):

- Mud crab: Viet Nam achieved success in 2003. In 2005, the hatcheries produced more than 3.5 million juveniles with a survival rate of 10–12 percent.
- *Babylonia* snail: 150 million spat were produced from hatcheries in 10 provinces. Average survival rate is 20–25 percent.
- Otter clam (*Lutralia philippinarum*): This is a high-value mollusc in Viet Nam with a price of about US$12–13 per kg. In 2004, artificial seed reproduction was a success. The survival rate was about 10–12 percent. A total of 3.0 million otter clam spat were produced in 2005.
- Hard clam (*Meretrix meretrix*): The production of artificial seed from hatcheries in 2005 was about 20 million.

TABLE 1
Research results and propagation of marine fishes, 2005

Species	Research institute	Quantity produced
Orange-spotted grouper (*Epinephelus coioides*)	RIA 1	400 000 fry
Cobia (*Rachycentron canadum*)	RIA 1	500 000 fry
Red drum (*Scaenops ocellatus*)	RIA 1	500 000 fry
Seabass (*Lates calcarifer, Psammoperca waigiensis*)	RIA II	400 000 fry
Mud crab, swimming crab	RIA II	3.0 million
Babylonia snail	RIA II	150 million
Otter clam (*Lutralia philippinarum*)	RIA 1	3.0 million spat
Hard clam (*Meretrix meretrix*)	RIA 1	20.0 million

Culture

Species for mariculture

Major mariculture species in Viet Nam and the sources of seed are shown in Table 2.

TABLE 2
Major species for mariculture in Viet Nam

Species	Sources of seed
Epinephelus coioides	Hatchery + Wild
E. tauvina	Wild + Hatchery
E. malabaricus	Wild
E. bleekeri	Wild
Rachycentron canadum	Hatchery
Lates calcarifer	Hatchery + Wild
Psammoperca waigiensis	Hatchery
Lutjanus erythropterus	Wild
Sparus sarba	Wild
Scaenops ocellatus	Hatchery
Siganus sp.	Wild
Mud crab	Hatchery + Wild
Swimming crab	Wild + Hatchery
Lobster	Wild
Babylonia snail	Hatchery + Wild
Sea urchin	Wild
Otter clam *(Lutralia philippinarum)*	Wild + Hatchery
Hard clam *(Meretrix meretrix)*	Wild + Hatchery

Cage culture

According to the Department of Aquaculture of the Ministry of Fisheries (2004), there were 40 059 cages in 2004 (excluding cages for cultivated pearls). Production of marine fish from cage culture in 2005 is estimated as 5 000 tonnes. Cage farming of lobster produced another 1 795 tonnes.

Cage culture is found mostly in the provinces of Quang Ninh, Hai Phong, Thanh Hoa, Nghe An, Ha Tinh, Phu Yen and Ba Ria–Vung Tau. There are two kinds of cages found in Viet Nam:

- Cages with wooden frame with a size of 3x3x3 m or 5x5x5 m. This is the most popular cage in most provinces.
- Norwegian-style cages (produced in Viet Nam) that are popular in Nghe An and Vung Tau with plastic frames that can withstand a Force 9–10 storm and waves.

Pond culture

Mariculture in ponds has been developed since 2002–2003 in some northern and central provinces. Fish species for this type of culture are *Epinephelus coioides, Lates calcarifer, Psammoperca waigiensis, Sparus sarba* and *Scaenops ocellatus*. Production of fish from pond culture is on average 12–13 tonnes per year.

Current status and problems of mariculture

Aquatic animal seed

Viet Nam has the technology for reliable reproduction of five mariculture species, but this is still mainly on an experimental scale in research institutes. The quantity of seed is insufficient and the price is high. Farmers usually source seed from the wild or import from China or Taiwan Province of China.

Grow-out culture

Viet Nam is developing mariculture in closed bays in coastal areas that are sheltered from waves and wind. This farming is done mainly by small-household-operated cages. For this reason, market production is not concentrated and the product is mostly sold for the live fish trade. Almost all households use trash fish as food for mariculture, causing negative environmental impacts. Pollution in some culture areas is critical due to high cage densities without master planning. Cage culture in the open sea is not developed due to high investment costs and marketing concerns for large volumes of product from such systems.

Fish disease

Fish disease is associated with high densities of farms and poor seed quality. Vaccine development through research has just started. However, vaccine development is difficult for marine fish farming because of the many species of fish that are cultured and the wide variety of diseases. For this reason, seed quality, environmental management of mariculture and disease prevention must be the highest priority.

Technology transfer

Transfer of technology started in 2004–2005 but considerable constraints remain. Difficult and high-risk technology and lack of capital are major problems that constrain the uptake of technology at the farm level.

Mariculture was developed to assist households in transferring from coastal fishing to farming. In the future, a diverse mariculture development is required, including cage culture, pond culture and polyculture (e.g. 1 shrimp crop and 1 fish crop per year) that may assist farmers to manage risk and help in poverty reduction. However, environmental problems need urgent attention to ensure that water quality can be maintained for sustainable development.

FUTURE DEVELOPMENT STRATEGY

By 2010, the plan of the Government of Viet Nam is to achieve a production of 200 000 tonnes of farmed marine fish per year. To achieve this target, given the current state of mariculture development, natural and social conditions, investment, technology and market, we consider the strategy for development of mariculture in Viet Nam from 2006–2010 as follows:

Seed reproduction

Seed is the first condition for development. It is necessary to hasten development of technology for seed production and the transfer technology to hatcheries. This requires:

- Research on reproduction technology that is based on a multispecies hatchery approach with species that have a high market demand. Emphasis should be placed on fish that can enter frozen market chains (red drum, sea carp, red seabream) and fish low in the food chain (*Siganus*, milkfish, mullet).
- Work to manage and control broodstock quality for high-value species and to expand research on genetic quality in broodstock.
- Studies on high-quality seed, including specific pathogen-free (SPF) seed production; and
- Exploration of vaccines for selected species with potential for high-volume production.

Hatcheries that are inactive or have limited activities should be rehabilitated and developed to increase the number and output of high-quality seed from hatcheries.

Commercial mariculture

The development of grow-out systems for mariculture requires a number of priority activities:

- Local governments should hasten the preparation of master plans to identify and plan areas for mariculture, including marine fish and mollusc culture. Local-level policies and methods for development of mariculture should be specified in the plans. Intensive cage culture should not be concentrated at one place.
- Research on new culture technology, high productivity, biosecurity and safe product is required to support development of a modern industry.
- Feeds and feed management need urgent attention (including use of floating food) to assist and encourage farmers to adopt quality formulated diets to reduce use of trash fish.
- Fish species should be developed for mass production, based on pelleted feed, for culture in cages and ponds. Focus should be on markets that accept fresh, frozen or filleted product, such as red snapper, mangrove snapper, red drum and seabream.
- Multi-species culture should be developed for cages in closed and semi-closed bays and for pond culture. Shrimp ponds can be used to culture marine fish to produce export products and improve the pond environment. Hasten polyculture in shrimp culture areas in order to reduce shrimp disease, increase the effective use of land and improve the environment.

Intensified cooperation with Asian and other countries should be promoted to learn and exchange experiences in seed reproduction and marine culture fish, disease prevention and more generally, to facilitate rapid development of sustainable mariculture.

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The Pacific Islands

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BACKGROUND

Mariculture is a primary development option for the Pacific region[1] because it is essentially a coastal region with a network of some 500 inhabited islands. The region covers an exclusive economic zone (EEZ) of 32 million km^2 comprising 8 million inhabitants. Three-quarters of the population live in rural areas, often in remote locations.

Geographically and culturally the Pacific is often divided into three main areas: Melanesia, to the west, comprises the bulk of the landmass; Micronesia, to the north, is mostly atoll formations; and Polynesia, the triangular area in the central and eastern part of the region, is a mixture of high volcanic islands and atolls. The Pacific region is a hotspot for ethno-biodiversity, which translates into a diverse setting for aquaculture development.

KEY COMMODITIES

Cultured pearls

The world's supply of cultured black pearls from black-lip pearl oyster (*Pinctada margaritifera*) is provided almost entirely by French Polynesia and the Cook Islands, where the oysters are naturally plentiful. In these countries the pearl industry is the second most important economic sector after tourism. French Polynesia reached a peak in annual production in 1999 valued at US$164 million (Institut des statistiques de Polynésie française). In the Cook Islands, a production of about US$9 million was achieved in 2000 (Cook Islands Government Statistics). Thereafter an overproduction of poor quality pearls and disease mortality (particularly in the Cook Islands) reduced the total value of exports to around US$128 million in 2005. Elsewhere in the region, pearl farms have been established in the Fiji Islands, Marshall Islands, Federated States of Micronesia, Solomon Islands, Kiribati, Papua New Guinea and Tonga.

Marine prawns

New Caledonia is the largest producer of marine prawns in the region. In 2004 the country produced 2 200 tonnes (worth US$22 million) of the western blue prawn (*Litopenaeus stylirostris*). The domestic demand is estimated at 540 tonnes (Source: Government Statistics).

There are a number of marine prawn farms operating in the Pacific Islands, such as in French Polynesia, Fiji, Vanuatu and Saipan, raising a variety of species (i.e. *Penaeus monodon*, *L. vannamei* and *L. stylirostris*).

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1 The region is defined in this report as that area encompassing the 20 Pacific Island member countries and territories of the Secretariat of the Pacific Community (SPC).

Kappaphycus seaweed

For the past decade Kiribati has been the main source of seaweed in the Pacific. In 1999, 1 200 tonnes were exported with a value of US$360 000. In the past five years, a single atoll, Fanning Island, has been almost the sole producer of seaweed

In the late 1980s, Fiji rejuvenated its seaweed farming and for five years after that exported around 500 tonnes per annum. Thereafter production declined drastically, reportedly due to domestic marketing and distribution problems. The government has recently launched an aggressive campaign to rejuvenate the industry in the Lau Group atoll lagoons.

In 2002, seaweed farming was revived in the Solomon Islands after an earlier project ceased in 1991. Although this programme has restricted its target sites, the production has increased exponentially from just 4 tonnes in 2002 to an anticipated export crop of 500 tonnes for 2006 (Source: Government Statistics).

Others

The Pacific is an important source in the global marine ornamental industry. Most of the trade involves wild-caught fish, corals and invertebrates. About 75 percent of the region's export is from Fiji, where the industry is worth some US$19 million.

Giant clam cultivation for the marine ornamental market is one of the most common forms of aquaculture in the region. Commercial hatchery production occurs in Fiji, Palau, Marshall Islands, Tonga, Vanuatu, Cook Islands, Kiribati, Samoa and American Samoa. There are probably between 30 000–50 000 giant clam pieces exported per annum.

Coral cultivation for the ornamental market is done in several countries, particularly Fiji, Vanuatu and Marshall Islands. The largest commercial farm, in Fiji, produces 25 000 pieces from 40 species. In 2003 the annual trade in live rock was estimated at 700 000 tonnes, almost entirely wild harvested, with just 50 000 pieces currently under cultivation.

Several species of marine fish are farmed for commercial purposes. In French Polynesia the majority of commercial barramundi farms have turned their interest towards the local fish species *moi* (*Polydactylus sexfilis*) and the batfish (*P. orbicularis*). Several countries raise milkfish (*Chanos chanos*) for the tuna baitfish industry. Other varieties of marine finfish are also farmed.

Mozuku seaweed (*Cladosiphon* sp.) has a sushi market in Japan, traditionally supplied from Okinawa Island. However the seaweed occurs naturally in the sub-tropical belt of the Pacific. In Tonga about 250–350 tonnes of *mozuku* is harvested per year, of which between 50–100 tonnes is cultivated. The dried product exported to Japan fetches up to US$150/kg.

Perhaps the most interesting technology to emerge in recent times is the use of crest nets or light traps to attract settling larvae. The use of crest nets has been tested for a number of years in the region, particularly in the Solomon Islands and French Polynesia. In the latter, one commercial operator handles up to 160 species of fish and crustaceans, targeting ornamental species. Trial production of food species has been also successful.

Marine aquaculture products demand, trade and markets

The major constraint to market access in the Pacific is its remoteness, which leads to poor transportation links. Freight costs are high and space is scarce. It is particularly so for the high-value fresh or live food markets overseas.

Processing technology for high-value food products has been applied to overcome the hurdle of sea freight and meet stringent quality controls. The best example of this is *mozuku* seaweed (*Cladosiphon* sp.) from Tonga and paradise prawns (*L. stylirostris*) from New Caledonia, which are exported by sea to the demanding sushi market in Japan where they are reconstituted and eaten raw. For *mozuku* seaweed a patented drying technology was developed that reduces the seaweed to 25 times its original volume.

Given the diverse range of produce and the distances between farming centers, the marketing chains tend to operate separately, and so there are few examples of cooperative marketing approaches in the region. There are also geopolitical divisions under which traditional trading partnerships have been well forged. For example, French territories enjoy a special trading relationship with the European Union, as do the United States of America affiliated territories with the mainland. However, some producers remain outside these arrangements, and much work needs to be done to break down trade barriers between countries within the region.

Unstable production in the past had constrained long-term market development and regionally coordinated efforts. This can be attributed to a variety of reasons such as natural disasters, currency devaluation, economic downturns, political instability and even apathy among farmers. Another destablizing factor has been the tendency to fall prey to "travelling salespersons" and "spot prices", so that inflated market opportunities have fuelled hopes of success that were unfulfilled and expectations of high profits that did not materialize. Such problems have set back long-term development.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

There are diverse types of fisheries in the Pacific but the majority of coastal fisheries are of a subsistence or semi-commercial nature. Commercial coastal fisheries often suffer from a "boom-bust" cycle caused by overfishing. In particular, this applies to slow-moving invertebrates such as trochus (*Trochus niloticus*) and sea cucumber (holothurians).

The consensus is that aquaculture may be a useful intervention to help sustain resource management of these types of fisheries, but it is unlikely that aquaculture alone will solve the problem. One reason for this is the long period before harvesting takes place. Also traditional tenure systems make it difficult to secure legally enforceable property rights, particularly if it impedes access to fishing grounds.

Many of the Pacific region's coastal dwellers in the rural areas rely on subsistence lifestyle and strong communal support. Therefore they often need cash for basic requirements, staple foods, school fees, church donations and other purposes.

The introduction of *Kappaphycus* seaweed has provided positive examples of mariculture providing rural livelihoods with household cash. Its relative ease of production and stable farm-gate price are suited to the rural lifestyle. Furthermore there are often few sources of cash income, and these may involve intensive manual labour such as copra making, sea cucumber collection or tuna fishing, which restricts the entry of women. Seaweed farming has therefore opened up an alternative pathway for women to earn money.

There is a general perception that the cash paid to women for seaweed is better directed towards essential household needs, i.e. education, health, food etc. as compared to the cash paid to men, which has been widely seen as being spent on household non-essentials such as alcohol.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Aquaculture research and development (R&D) has been a challenging experience for the region. Many of the early ventures failed because projects were simply initiated on the basis of their technical feasibility for cultivation and did not incorporate a holistic approach that included economic (marketability), social (labour costs) and environmental (impact on biodiversity) factors.

Even so, the applied research necessary to properly assess the biotechnical basis for aquaculture remains incomplete for many species. Furthermore, development agencies often lack the skills to translate research findings into practical extension training modules that farmers are able to understand and apply. There remains a critical need to build extension services capacity.

Similarly, there is limited capacity for socio-economic and environmental planning. Very few countries have proper systems for governance of aquaculture. There are hardly any policies and regulations specific to managing the aquaculture sector.

Bottlenecks in technology transfer have occurred when government-funded programmes became competitors with the private sector. The underlying requirement is that there is a need for a clear and agreed national development strategy that outlines the roles and responsibilities of key stakeholders within the sector. Such fundamental planning is lacking in many countries.

The Pacific region is fortunate to have a network of about a dozen key mariculture facilities in operation. Most are operated under government programmes that make collaboration possible through inter-governmental organizations such as the Secretariat of the Pacific Community (SPC). Essentially this provides a focal body through which lessons can be shared and a country can avoid the duplication of trials and pitfalls experienced elsewhere. Such a body also enables the region to prioritize common issues and act in a collective manner to deal with them.

SECTION 3

Special presentations and perspectives

Demand, markets and trade of farmed fishery products in China

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INTRODUCTION

After 1985, the aquaculture sector in the People's Republic of China developed rapidly. During this period, the structure of the fishery industry changed significantly. Shortage of farm products no longer occurred. Instead, there was abundant supply in some regions, and in other regions supply soon exceeded demand, especially of traditionally farmed fishes. Subsequently, the farmed species changed from traditional to special high-value species.

During March to May 2005, we made a study on the supply and consumption characteristics of farmed seafood from 1985 to 2003. Our findings are reported below.

STUDY OBJECTIVES AND METHODS

Study objectives

The study analyzed the supply properties of farmed aquatic products, the current and style of demand, the price and income elasticity of farmed fishes and the international marketing of farmed fishes. The main study species were traditional freshwater farming fishes (bighead carp, silver carp, grass carp, black carp), tilapia, freshwater prawn (*Macrobrachium rosenbergii*), scallop and sea-mussel.

From 1994 to 2003, the average output of traditional freshwater fishfarming was over 86 percent of the total output of freshwater farming. The production cost of most traditional freshwater fishes was low and seed was easy to obtain. For this reason, their price was moderate; these fishes are the most important fishery products for the population. In addition, the statistical data on output and price of freshwater farmed fishes were easy to obtain and covered a long period. Thus freshwater fishes became the first research priority for studies on price, income and consumption trend of fishery products.

The study also included tilapia and freshwater prawn (*Macrobrachium rosenbergii*) for the following reasons:

- the average price of these commodities is higher than the average price of traditional freshwater farmed fishes;
- the farming model is different from traditional freshwater farming; tilapia for instance is industrial fish farming at high density;
- different consumer preferences;
- there is a long farming history with good statistical data for these species and their output is much higher than other special farmed species.

For mariculture species, we selected scallop and sea-mussel because the output of bivalves is much higher than for other seafood. In the past 20 years, the output of farmed shrimp and fish has been much lower. The influences of farmed shrimp and fish on consumption are weak. In fact, the fast development of marine shrimp and fish farming started from the middle of last century and until 2002, there were no routine statistical data for each species in the fishery annual statistics. The other reasons were that as the consumption of scallop and sea-mussel is large and their price is moderate, it was easy to obtain the data on price.

Study methods

From the "Chinese Statistics Almanac", we obtained the demand elasticity, income elasticity and price elasticity of different fishery products. We then studied the demand and marketing characteristics of farmed fishery products. As there is linearity pertinence between the consumption of fishery products and interpreting variables, we adopted the linearity model for studying the elasticity indices. We think the consumption (q) is impacted mainly by income of resident (y), price of fishery products (p1), price of meat and its goods (p2) and price of poultry and eggs (p3). Thus the function is as follows:

$$q=c(1)+c(2)*y+ c(3)*p1+ c(4)*p2+ c(5)*p3+\varepsilon \qquad 1*$$

In function 1*, the c (1) is constant. The c (2), c (3), c (4) and c (5) are coefficients of explanatory variable and random disturbance. By the function, the income elasticity and the price elasticity are as follows, respectively:

$$E_y = \frac{dq}{dy} * \frac{y}{q} \qquad E_p = \frac{dq}{dp} * \frac{p}{q}$$

As we did not have enough consumption data for traditional farmed fishes, tilapia and *Macrobrachium rosenbergii*, we adopted the definition to calculate the income elasticity and the price elasticity of those products.

Data sources

The resident income and consumption of fishery products per capita are from the "Chinese Statistics Almanac". The consumption of marine products and freshwater products per capita is calculated by their proportion in the total fishery products on the basis of total consumption of fishery products per capita. The output data is from the "Fishery Statistic Yearbook of China" published by the Fishery Bureau of the Agriculture Ministry.

The consumption of traditional freshwater farmed fishes, tilapia and freshwater prawn is calculated by the output times consumer coefficient productive-marketing. The consumer coefficient (retail quantity/buying quantity by pond) is from our investigation. The coefficients of traditional freshwater farmed fishes, tilapia and freshwater prawn are 30 percent, 30 percent and 40 percent, respectively. The prices for them are calculated according the bargaining price of the main seafood market provided by the journal of "Scientific Fish Farming".

THE SUPPLY CHARACTERISTICS OF FARMED PRODUCTS (1985–2003)

Output of farmed products in relation to fishing output

In the past 20 years, the farmed output increased nine times from 3.09 million tonnes in 1985 to 30.27 million tonnes in 2003 (Figure 1). The growth rate was over 10 percent during the periods 1986–1988 and 1996–2002. With increasing farming output, the proportion of farming products to total output of fishery products also increased. In 1985 the proportion was 44 percent and in 2003 it was 64 percent. In 1993 aquaculture output had exceeded the output from capture fisheries.

Figure 1
Growth of fishery production, 1985–2003

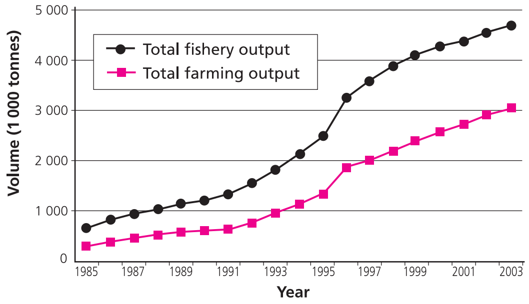
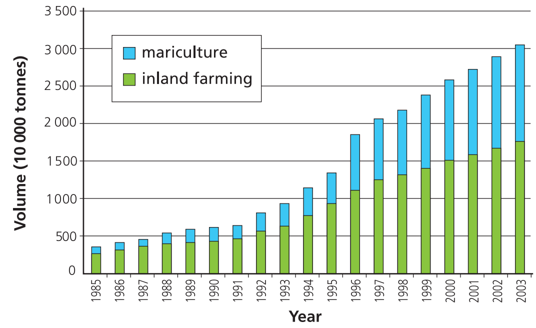


Figure 2
Marine and inland aquaculture production



Increasing of proportion of marine farming output

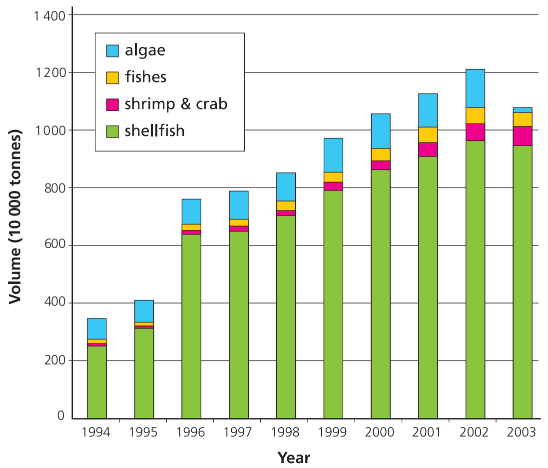
In 2003 the outputs of inland farming and marine farming attained 17.74 and 12.53 million tonnes, respectively (Figure 2). The proportion of marine farming output to total farming output increased from 23 percent in 1985 to 41 percent in 2003. The annual rate of increase was stable.

Structural surplus of farmed fishery products

The proportion of traditional farmed fishes to freshwater farmed fishes was 86 percent in 1994 and 65 percent in 2003. In marine farming, the proportions of shellfish, algae and fishes, including shrimp and crab, to total output are 75–85 percent, 10–20 percent and 2–5 percent, respectively.

In order to resolve the problem of structural surplus of farmed fish products, the fishery administration pays attention to the adjustment of industrial structure and in recent years, the output of some special species increased greatly. A good example is the growth of tilapia. In 1994 the output of tilapia was only 0.236 million tonnes, in 2003 it rose to 0.806 million tonnes. Today the farmed output of tilapia in China is about 65 percent of the total farmed output of the world.

Figure 3
Marine aquaculture by species groups, 1994–2003



Main farming area

Main freshwater farming area

The main freshwater farming areas are in Guangdong, Hubei, Jiangsu, Hunan and Anhui provinces. Between 1985 and 2003, the output from these areas grew constantly. During 1986 and 1987, the growth rate was between 10 percent and 30 percent (Figure 4). Between 1989 and 1991, the growth rate was low. For instance, the output of Jiangsu Province decreased in 1991. Rapid growth rate returned in the mid-1990s.

Figure 4
Aquaculture production in different Chinese provinces, 1985–2003

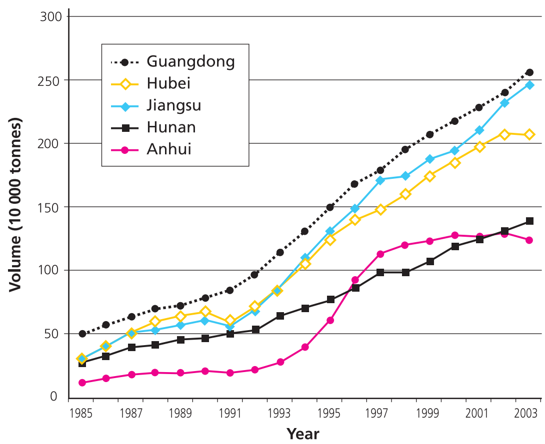
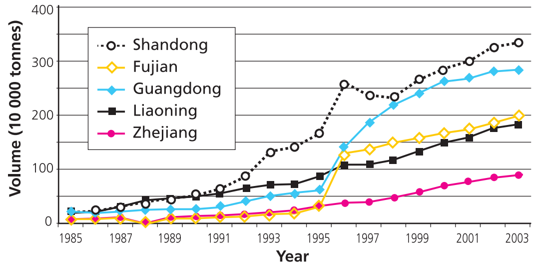


Figure 5
Increasing trend of marine farming in the main provinces provinces, 1985–2003



Main marine farming area

The main marine farming areas include Shandong, Fujian, Guangdong, Liaoning, Zhejiang and Guanxi provinces. In 2003 the total output of these provinces was 94 percent of the total output of China. The outputs of Shandong and Fujian were 26 percent and 23 percent, respectively (Figure 5).

DEMAND CHARACTERISTICS AND CONSUMER PREFERENCES FOR AQUACULTURE PRODUCTS

In order to make a quantitative analysis of the demand characteristics and consumer preferences, we calculated the different coefficients of farmed fishery products. The demand quantity of fishery products is affected by the level of resident income, the price of fishery products, the price of meat and its goods and the price of eggs. The different coefficients are listed in Tables 1 and 2.

TABLE 1
Price and income elasticity of fishery products, 1994–2003

Year	TAC[1]	TPE	SEMFP	IEUR	PEUS	SEMFPUR	IERR
1994	0.6079	-1.5674	1.1873	0.3024	-2.6513	1.7077	0.8600
1995	0.5642	-1.5414	1.2899	0.2934	-2.8122	2.0010	0.7570
1996	0.5834	-1.5367	1.2679	0.3044	-2.9647	2.0800	0.7792
1997	0.6034	-1.5008	1.3038	0.3141	-2.9548	2.1827	0.8071
1998	0.6215	-1.3599	1.1436	0.3146	-2.6222	1.8750	0.8624
1999	0.6335	-1.1917	0.9743	0.3277	-2.3282	1.6185	0.8567
2000	0.6746	-1.2140	0.9612	0.3668	-2.4806	1.6701	0.8478
2001	0.6894	-1.1094	0.9192	0.3802	-2.3014	1.6213	0.8412
2002	0.6393	-0.8863	0.7791	0.3368	-1.7416	1.3018	0.8384
2003	0.6673	-0.8498	0.7693	0.3619	-1.7271	1.3295	0.8227

[1] TAC: Total income elasticity; TPE: Total price elasticity; SEMFP: Substitute elasticity of meat and its goods for fishery products; IEUR: Income elasticity of urban resident; PEUS: Price elasticity of urban resident; SEMFPUR: Substitute elasticity of meat and its goods for fishery of urban resident; IERR: Income elasticity of rural resident.

TABLE 2
Price and income elasticity of fishery products, 1994–2003

Year	PERR[1]	SEMGFPRR	IEMFF	PEMFF	SEEFP	IEFFF	PEFFF
1994	-0.4622	0.6216	0.9162	-0.1320	0.2484	0.8167	0.2166
1995	-0.4217	0.6266	0.8602	-0.1120	0.2476	0.7461	0.1902
1996	-0.4081	0.5979	0.8308	-0.0832	0.2533	0.8520	0.1993
1997	-0.4013	0.6191	0.8705	-0.0918	0.1976	0.8636	0.1961
1998	-0.3861	0.5765	0.9602	-0.0877	0.2061	0.9486	0.2002
1999	-0.3451	0.5010	0.9209	-0.0749	0.1240	0.8962	0.1614
2000	-0.3421	0.4809	0.9911	-0.0806	0.1061	0.9395	0.1791
2001	-0.3160	0.4649	1.0239	-0.0842	0.1070	0.9454	0.1725
2002	-0.2888	0.4508	0.9614	-0.0704	0.0890	0.8615	0.1424
2003	-0.2716	0.4366	1.0193	-0.0955	0.0852	0.8803	0.1957

[1] PERR: Price elasticity of rural resident; SEMGFPRR: Substitute elasticity of meat and its goods for fishery products of rural resident; IEMFF: Income elasticity of marine farming fish; PEMFF: Price elasticity of marine farming fish; SEEFP: Substitute elasticity of egg for fishery products; IEFFF: Income elasticity of freshwater farming fish; PEFFF: Price elasticity of freshwater farming fish.

Increasing of total and per capita consumption

The supply of fishery products in China is now abundant. With the growth of the population and improving incomes, the consumption and consumption preferences in China have been increasing in recent years. In 1985 the demand of fishery products was 1.36 million tonnes, while in 2003 it was 6.79 million tonnes (Figures 6 and 7).

Figure 6
Demand of farming products, 1985–2003

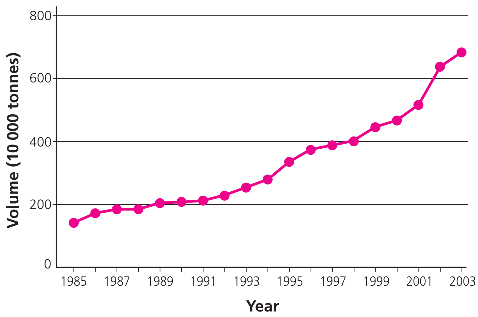
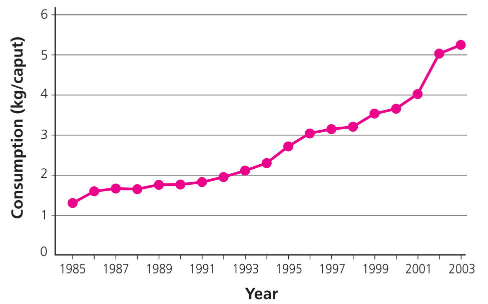


Figure 7
Per capita demand for aquaculture products, 1985–2003



With improving personal incomes, the demand per capita increased quickly. In 2003 the demand per capita was 5.3 kg, which is three times that in 1985 of 1.3 kg.

Consumption demand of rural residents is lower than that of urban residents

From Tables 1 and 2, we find that the income elasticity of townspeople is lower than the income elasticity of rural dwellers. However, the price elasticity of urban dwellers is larger than in rural areas. Thus, we can conclude that the income of townspeople is relatively higher and they have a higher demand for fishery products. For the townspeople, fishery products are necessary goods, but for the rural residents, even if they have higher demand for fishery products, their income limits their consumption. We can anticipate that rural residents will enhance their demand on fishery products with an increasing income. Thus income is the most important factor that influences demand for fishery products.

The townspeople's consumption of fishery products increased from 0.779 million tonnes in 1985 to 4.5 million tonnes in 2003. Consumption in the rural area increased from 0.58 million tonnes in 1985 to 2.3 million tonnes in 2003. In 1985 the urban consumption of fish farming products per capita was 3.3 times that of rural areas; in 2003 it had gone down to 1.8 times. However, the absolute consumption in urban areas was 2.38 kg in 1985 and 5.6 kg in 2003 (Figures 8 and 9).

Figure 8
Consumption trend of farmed products

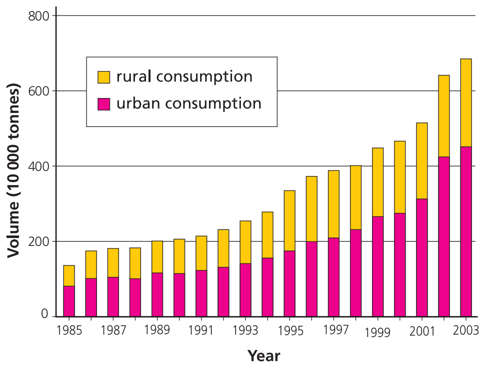
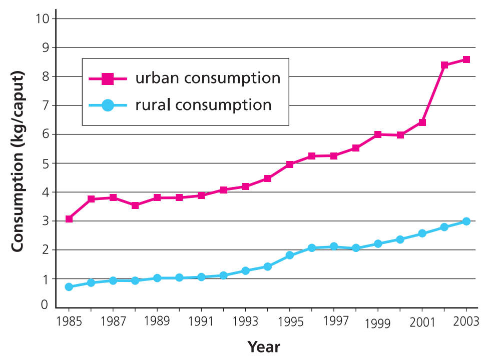


Figure 9
Consumption of agriculture products per capita



Fishery products become necessities and population growth and urbanization raise demand for farmed fish

From Tables 1 and 2, the price elasticity of fishery products has been decreasing since the mid-1990s. This indicates that fishery products are becoming household necessities. However, during the period, the price and substitute elasticity also went down simultaneously. When the substitute elasticity is large but the price change is small, consumers will buy a substitute, which induces an expansion in price elasticity. A decreasing substitute elasticity therefore means that fish products cannot be substituted.

From 1985 to 2003, the total population of China increased from 1 060 million to 1 300 million. During the same period, the consumption per capita increased only three times, although the total consumption increased four times the growth of the population. At the same time urbanization has been drawing migration from the rural areas. These trends increased demand for farmed fish products. Studies have indicated that with urban populations increasing by 100 million, the demand for fish products increased by about 57 000 tonnes.

Promoting marine farming mariculture

From Tables 1 and 2, the income elasticity of demand for fishery products is between 0 and 1. This indicates that the demand increases with improving income. With better transportation and refrigeration, inland people will have better access to fishery products. However, due to the limited natural resources, the capture output will not increase accordingly. The deficit will be made up by marine farming products and imports. Freshwater farming will be limited by the scarcity of freshwater resources. More investments therefore should be directed to upgrading technology and expanding the production of high-quality fishery products. To satisfy local demand, measures should be taken to import more of the fishery products that are in short supply.

Improving marketing systems to alleviate imbalance between supply and demand

Some 80 percent of the fishery products are produced in eastern China, 18 percent in central China and 2 percent in western China. In addition, due to poor processing and freezing technology, the products can only be sold in markets near the production areas, thus making it difficult for people far away to buy fishery products. In addition, the three major fishing grounds are closed for certain periods to allow the fishery resources to recover. During this period, there is supply shortage of marine-caught products. To solve these problems, a full-functioning marketing system should be built. More processing factories should be set up in producing areas that can process the fishery products as soon as they are caught or harvested. This will reduce the transportation cost of processed products and enhance their competitive edge.

Improving processing

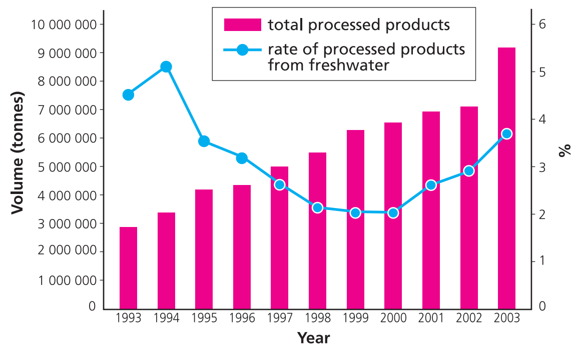
Chinese prefer fresh and live fishes. With improving living standards, the Chinese people have also begun to like processed fishery products because they would like to save more time for other activities. However, problems remain in the fish-products processing industry. Firstly, the scale of processing enterprises is small. Secondly, the volume of processed fishery products is low and the technology level is low as well. Thirdly, 95 percent of Chinese fishery-products processing enterprises are located in the eastern coastal area, especially in Shandong and Zhejiang provinces, and are mainly engaged in the processing of marine products. The processing of freshwater farmed fish remains at a very low level. In 2003 the processed freshwater farmed fish was only 7.75 percent of total output, and in inland areas, the rate was even lower at 3.68 percent, although after 1999 there was a slight increase in processed products from inland areas (Figure 10).

Increasing demand for high-quality fish products

Economic development has also stimulated increasing demand for highquality fish products. For instance, the import of salmon has risen from 25 155 tonnes in 2000 to 74 205 tonnes in 2003. The consumption of salmon is concentrated in coastal areas such as Jiangsu, Shanghai, Beijing and Guangzhou. In 2003 the volumes of imported salmon in Jiangsu and Shanghai were 55 percent and 29 percent of total salmon imports, respectively. Much of the sale is in hotels, restaurants and supermarkets. The consumers are mainly residents with high income and visitors from Japan, China, Hong Kong SAR and Taiwan Province of China.

In the past three years, it was noticeable that consumers with high income have been reducing their consumption of aquaculture products produced in China and increasing their consumption of imported products. The main reason is that these segments of the population are wary of the safety of China's aquaculture products.

Figure 10
Rate of processed fishery products and rate of processed farmed freshwater products



IMPORT AND EXPORT OF CHINA'S FISHERY PRODUCTS

Comparative advantage of the main fishery country in the world

The comparative advantage of seafood in China is favourable, and the growth rate is higher than the average for developing countries. On the other hand, it is still some distance from the progress attained by some countries, for example, Thailand.

Characteristics of China's fishery exports

China's main agriculture products for export are vegetables, fruits, animal products and fishery products. The export value of fishery products is increasing, and the ratio in agricultural products is rising, indicating there are good prospects for China's export of fishery products (Table 3). From 1999 to 2003, the export value of fishery products increased from US$2.97 billion to 5.49 billion.

The main characteristics of the export of fishery products of China are as follows:

- Firstly, the products mostly come from the provinces along the coast. The export value of fishery products from coastal areas such as Shandong, Guangdong, Liaoning, Zhejiang and Fujian makes up 92 percent of the total. Shandong and Liaoning are the main source of processed products, and Guangdong, Zhejiang and Fujian are the sources of ordinary exports.
- Secondly, the exports are mainly farmed products and include eel, prawn and frozen fish. In 2003 the export of aquaculture products such as shrimp and eel made up 47 percent of ordinary exports.
- Thirdly, seafood is mainly exported to a few countries such as Japan, the United States of America and the Republic of Korea, as well as to China, Hong Kong SAR.

TABLE 3
The export value (US$ billion) of fishery products, 1999–2003

Year	Export value of fishery products	Export value of agriculture products	Ratio of export value of seafood in agriculture products (percent)
1999	2.97	13.39	22.2
2000	3.83	15.62	24.5
2001	4.19	16.7	26.1
2002	4.69	18.14	25.9
2003	5.49	21.43	25.6

Characteristics of fishery products imports

China also imports a large volume of fishery products, mainly from the Russian Federation, Peru, the United States of America and Japan. The import values for these countries from 1999 to 2003 were US$1.29 billion, 1.85 billion, 1.88 billion and 2.48 billion, respectively.

The main imported products are fish flour, cod and frozen fish. The imported fishery products are increasingly varied. Some superior products such as live lobster, live crab and grouper as well as inferior fishery products are imported.

Problems with fish trade

With rapid economic development, the trade in fishery products has achieved a high growth; but problems with exported seafood persist, including:

- technical barriers to trade are becoming more and more common;
- the system of information management is underdeveloped;
- the corporations' activities in exporting are not well organized; and
- many corporations are not aware of the importance of a brand in marketing and the advertisements about seafood are not very effective.

Among these problems, the importance of the brand in marketing is very evident. In China, there are not many seafood brands, although there are a few famous brands. However, more and more people pay attention to the brands of the products in the modern world. So it is a good opportunity for foreign corporations entering into China's market, and it is important to build the corporate image and brand. The "place brand" (place of origin) is a very important feature of the image of an aquatic product and for the production of seafood is mostly connected with the origin. For instance, salmon (Norway), tuna (Japan), lobster (Australia), hairtail from the East China Sea and scallop from the Yellow Sea are well known to consumers. Thus, the seafood companies could take advantage of the "place brand" to promote their products. For example, Norway represents 71 percent of Chinese imports of fresh and frozen Atlantic salmon and 34 percent of fresh and frozen Pacific salmon.

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The status of mariculture in northern China

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INTRODUCTION

The People's Republic of China has a long history of mariculture production. The mariculture industry in China has achieved breakthroughs in the hatchery, nursery and culture techniques of shrimp, molluscs and fish of high commercial value since the 1950s.

The first major development was seaweed culture during the 1950s, made possible by breakthroughs in breeding technology. By the end of the 1970s, annual seaweed production had reached 250 000 tonnes in dry weight (approximately 1.5 million tonnes of fresh seaweed). Shrimp culture developed during the 1980s because of advances in hatchery technology and economic reform policies. Annual shrimp production reached 210 000 tonnes in 1992. Disease outbreaks since 1993, however, have reduced shrimp production by about two-thirds. Mariculture production increased steadily between 1954 and 1985, but has been growing exponentially since 1986, mostly driven by mollusc culture. Mollusc culture in China began to expand beyond the four traditional species (oyster, cockle, razor clam and ruditapes clam) in the 1970s. Mussel culture was the first new industry to emerge, followed by scallop aquaculture in the 1980s. Abalone culture has become a major industry in the 1990s. Traditional oyster and clam culture has also advanced and expanded in recent years. Now more than 30 species of marine molluscs are cultured commercially in China. Because of the rapid development in recent years, mollusc culture has become the largest sector of the Chinese mariculture industry, accounting for 81 percent of the total production by weight.

Therefore, the industrialization level and culture techniques for the major species in China have reached an advanced international level, with some leading the world aquaculture sector. China is also the largest country in mariculture.

Marine aquaculture has grown rapidly over the last decade. Marine cultivable areas in China, which include shallow seas, mudflats and bays, are estimated to occupy more than 1.33 million ha, as most marine plants and animals can be cultivated within the 10 m isobath using current culture technologies. In 2002 the area under cultivation and the output reached 1 352 000 ha and 12.1 million tonnes, respectively.

The principal species cultured in northern China are listed in Table 1.

TABLE 1
Marine species cultured in northern China

Molluscs	*Crassostrea gigas, C. plicatula, C. rivularis, C. talienwhensis, Chlamys farreri, Argopecten irradians, Patinopecten yessoensis, Mytilus edulis,Ruditapes philippinarum, Meretrix meretrix,Cyclina sinensis, Mercenaria mercenaria, Mactra antiquata, M. veneriformis, Saxidomus purpuratus, Tegillarca granosa, Scapharca subcrenata, S. broughtonii, Sinonovacula constricta, Haliotis discus hannai, H. gigantea, Rapana venosa, Bullacta exarata*
Marine fish	*Pagrus major, Lateolabrax japonicus, Fugu* sp., *Paralichthys olivaceus, Scophthalmus maximus, Cynoglossus semilaevis, C. trigrammus, Kareius bicoloratus, Verasper variegates, Sebastodes fuscescens, Mugil cephalus, Liza tade, Hexagrammos otakii, Seriola lalandi*
Crustaceans	*Fenneropenaeus chinensis, Penaeus monodon, P. japonicus, P. merguinsis, Litopenaeus vannamei, Eriocheir sinensis, Callinectes sapidus, Scylla serrata*
Seaweeds	*Laminaria japonica, Undaria pinnatifida, Porphyra yezoensis*
Echinoderms	*Apostichopus japonicus, Strongylocentrotus intermedius, S. nudus*

HATCHERY SEEDLING PRODUCTION TECHNOLOGY OF MAIN CULTURED SPECIES

Molluscs

Many species of molluscs (e.g. scallop, oyster and abalone) can be hatchery reared with well-developed technology. The following sections describe the scallop and abalone hatchery procedures.

Scallop (Patinopecten yessoensis)

Breeding and larval rearing

Broodstock culture: Broodstock are selected in late winter or early spring. They are then transferred to conditioning tanks where water temperature is initially 2–3 °C. Water temperature is then increased daily by 0.5 or 1 °C until it reaches 7 °C. This temperature is kept stable until spawning. During conditioning, broodstock are fed either on artificial diet or unicellular algae, mostly *Phaeodactylum tricornutum, Chaetoceros muelleri, Monochrysis simplex, Isochrysis galbana, Tetraselmis tetrathele* and *Nannochloropsis oculata.*

Spawning, fertilization and hatching: Before spawning occurs, the water is prepared with the temperature at 10.5 °C. When the density of eggs reaches about 30 per ml, the aeration must be stopped and the parent scallops removed from the tanks. After the spawning is over, the water in the hatching tanks should be stirred with swing boards for 30 min to prevent the eggs from sinking to the bottom.

Larval cultivation: The rearing density depends on the rearing technique, food supply, capacity of the tanks and the quality of larvae. It ranges from 5–15 larvae per ml. During the period of larval rearing, the feeding behaviour and growth of the larvae are observed every morning before the water is renewed. In general, the normal larvae are usually swimming in the upper and middle layers of the water. The feeding ration can be adjusted according to the food content in the stomach of the larvae. The number of larvae should be counted and their shell lengths measured every two or three days.

The growth and development of larvae are closely related to salinity, temperature, rearing density, water quality and food supply. Under suitable rearing conditions as mentioned above, the eyespot, which is located in the stomach region, will appear 18 days after fertilization, with the shell height at 190–200 µm.

Spat collection: The appearance of the eyespot is an indication that the larvae are approaching the settling stage. Once the eyespot appears, the larvae should be sieved and transferred to another well-cleaned tank. The spat collectors are then put into the tank for larvae to settle on as soon as the transfer is completed. Two kinds of collectors are commonly used in northern China. One is made of palm fibre rope and the other of pieces of polyethylene net.

Nursery culture

Nursery or intermediate culture involves transfer of the spat to the open sea and rearing them until they attain 7 mm in shell height. Before transfer, the temperature of the rearing water should be lowered by 1–2 °C every day to approximate the temperature of the sea. This is important for increasing the survival. Each transfer leads to better survival and better growth rate. The water temperature of the sea area must reach 5 °C when the spat are transferred.

Because of the differences in the size of spat, condition of the sea area, culture materials and management, high mortality occurs after the spat are transferred to the open sea. At present, the survival rate in nursery culture ranges from as low as 10 percent to 30–40 percent.

Two kinds of material are used at present. One is a plastic pipe, 60 cm long and 25 cm in diameter, covered with plastic net (mesh smaller than the shell height of the spat) at both ends. The other, which is more common, is made of polyethylene bags. The size of the bag depends on the size of the spat collectors and is generally 30x40 cm. Every ten bags are strung together on a rope.

Abalone (e.g. **Haliotis discus hannai***)*

Commercial abalone seed production was accomplished in 1987 in Dalian, Liaoning. From 1987, abalone aquaculture in China grew steadily, with most research focused on the development of hatchery seed production techniques and grow-out modes. A series of key techniques involving spawning, larval rearing and juvenile and seed nursing were established. Sufficient seed supply is crucial to the development of abalone mariculture. All abalone seed are hatchery produced with sophisticated technology The technology to produce hybrid and triploid abalone has been successfully developed by researchers and is ready to be introduced to the commercial production sector.

Seed hatchery production

<u>Broodstock selection and conditioning</u>: Seed production typically begins in early spring with broodstock conditioning and gradually elevated temperatures and stabilization at 20 °C. The most widely used and effective method for abalone to ripen is by effective accumulative temperature (EAT) control. Meanwhile, plenty of algal food (*Laminaria japonica*, *Undaria pinnatifida* and *Ulva pertusa*) should be provided with this conditioning method.

<u>Spawning and hatching</u>: To induce spawning, well-developed abalones are exposed to air for desiccation and then subjected to ultra-violet-irradiated seawater. Adult spawning is usually induced by combined thermal shock and UV-treated seawater exposure. Males usually are induced one hour later than females because they are more sensitive to inducement. Fertilized eggs are incubated at 21–22 °C.

<u>Larval cultivation</u>: Approximately 60 hours postfertilization, *H. discus hannai* larvae are ready for settlement. Eyed larvae are set on the collecting plates made of transparent corrugated plastic that is diatom-precoated for *H. discus hannai*. The diatoms must be supplied in sufficient quantities as well as be of good quality to ensure the growth and survival of postlarvae. Water quality and light level should be carefully controlled during this critical period.

Juvenile nursery: Juveniles are manually moved from settlement plates to nursery culture plates at the size of 3–7 mm. For *H. discus hannai*, spat are usually transferred to large punctured plastic plates with dark colour. During early juvenile stages, an artificial diet is exclusively used as food supply. Several commercial diets from various feed manufacturers are available to aquaculturists. The major ingredients of artificial diets are dried kelp powder and fish meat powder. Fresh kelp is the principal food for older juveniles. The quality of artificial diet plays an important role in post-settlement survival.

Challenges to abalone mariculture

Mortality frequently occurs during the first month of the juvenile phase, following the movement of juveniles from settlement plates to the nursery culture plates, especially when the juveniles are taken off the diatom plates at <5 mm shell length. It is generally believed that the change of feeding habits is the major cause of this high mortality. Survival in this critical nursery period had dropped to lower than 5 percent at the lowest level during the early 1990s. Survival of early juveniles has been much improved by hybridization breeding, lowering juvenile density in the collecting plate and extension of diatom feeding, therefore, allowing the juveniles to be removed at a larger size than normal to the nursery culture plates. In particular, hybridization was made between Japanese and Chinese broodstock to produce hybrid seed. When all diatoms on the settlement plate are consumed, juvenile abalone (approximately 2–3 mm) are transferred to another batch of transparent corrugated plastic plates that are well covered by diatoms. Therefore, size of juvenile abalone reached 5–7 mm when transferred to the nursery culture plate, enhancing the adaptive ability of juveniles to artificial diets. The practice of transferring juvenile abalone is now becoming part of routine hatchery procedure. With the application of hybridization and plate-transfer techniques, production of *H. discus hannai* remains stable in the northern Chinese coastal areas.

The mortality problem, however, was not solved completely due to incomplete understanding of the physiological variation associated with the change of feeding habits following larval metamorphosis. In addition, a lack of quality control with respect to broodstock often leads to failure of utilization of heterosis. Hybrid abalone seed have now been widely adopted throughout the northern coasts. Nevertheless, breeding of high-quality lines of abalone will be the best solution in terms of genetic modification.

Availability of adequate commercially formulated diets is another problem for the abalone aquaculture industry in China. Abalone is a slow feeder, therefore, reducing leaching of water-soluble ingredients from artificial diets is a key to good diets. Furthermore, dietary essentials should be balanced to meet the nutrient requirement of abalone. As yet, however, the nutritional requirements of the cultured species are not yet fully demonstrated.

Echinoderms

Sea cucumber

Apostichopus japonicus is the only species of sea cucumber to be cultured in northern China. This is due to its high meat quality and the success of commercial hatchery techniques.

In the early 1980s, the shortage of sea cucumber seed was a bottleneck for developing aquaculture. The Ministry of Agriculture prioritized setting up hatcheries for sea cucumber (*A. japonicus*) and improving techniques for seed production. Since then, sea cucumber farming has become a vigorous sector in mariculture.

The procedure for artificial reproduction of sea cucumber is as follows:
Broodstock condition and spawning

- Broodstock collection: Broodstock are collected from late May to early July.
- Broodstock care in land-based tanks: Broodstock are held at 30 individuals per m^3, with dissolved oxygen (DO) over 5 mg/liter, and a feeding rate about 5–10 percent of body weight.
- Spawning stimulation: Spawning is induced by thermal shock (water temperature raised by 3–5 ºC) and desiccation followed by seawater jet for 10–15 min.
- Fertilization: Artificial spawning allows the hatchery operator to better control the concentration of spermatozoa and the stocking density of eggs. The maximum density is 1 million eggs per m^3 in hatchery tank.
- Hatching: The hatching rate may exceed 90 percent.

Larval rearing

Rearing the pelagic stages of *A. japonicus* requires considerable attention and constant monitoring of the culture medium.

Larval density: In order to ensure fast growth and a high metamorphosis rate, larval density should be maintained at between 3 to $4x10^5$ individuals/m^3.

Feeding: The use of different species of microalgae is crucial for the development of the larvae. *Dunaliella euchlaia, Chaetoceros gracilis, C. muelleri, Nizschia closterium* and *Phaeodactylum tricornutum* can be used to feed the larvae. The most important species are *D. euchlaia, C. gracilis* and *C. muelleri,* whereas *Dicrateria zhanjiangensis, Isochrysis galbana* and *Chlorella* sp. are usually added as a supplement but are never used alone. For a balanced diet, a mixture of two to three species is highly preferable. The microalgae are fed at a concentration ranging between 10 000 and 40 000 cells/ml. Food levels are increased gradually as the larvae develop. In order to enhance larval growth and decrease the rate of malformation of the young sea cucumbers, marine yeast and/or photosynthetic bacteria (PSB) are often supplied.

Water quality: High-quality seawater in a sea cucumber hatchery is an important prerequisite. Research findings indicate that numerous physical and chemical factors (e.g. temperature, pH, salinity, ammonia, DO, heavy metal concentration, turbidity, etc.) will influence the success of culture. As these parameters tend to vary significantly from one region to another, careful monitoring of the seawater quality is essential.

Selection and use of settling bases: The traditional substrates used for the settlement of the sea cucumber juveniles are frames fitted with fine polyethylene (PE) or polypropylene (PP) cloth. In recent years, some hatcheries have started to use PE corrugated plates measuring 50×50 cm fixed together in stacks of 8–10 pieces. This latter method has been used with some success. In the traditional method, benthic diatoms need to be cultivated on the settling bases before they can be used. Currently, some hatcheries no longer cultivate benthic diatoms, but rather provide a food supply soon after the juvenile sea cucumbers have settled. This method has two advantages: no equipment is needed to rear benthic diatoms and the settling plates are easier to clean during routine hatchery operations. The settled sea cucumbers are fed with benthic diatoms that have settled on specifically designed mesh bags or other materials placed in the rearing tanks and with a powdered macroalgae soup typically prepared using *Sargassum* spp. such as *S. thunbergii.* The correct feeding rate is essential to ensure a high survival rate of the juveniles.

Juvenile rearing

Rearing juvenile sea cucumbers may take several months, but may require as long as six months if the rearing conditions are not favourable.

Food: The food must be free of contamination, be of the right particle size and contain all the essential nutrients. A balanced diet not only accelerates the juvenile sea cucumbers' growth rate, but also increases their survival rate.

Transfer of the juveniles: Juvenile sea cucumbers are particularly vulnerable during the early rearing stages. High mortality rates are caused by high density, overfeeding, faeces on the settling plates and competition for space among themselves and with other opportunistic organisms such as *Ciona intestinalis.* This species of tunicate can also secrete a toxin that can kill juvenile sea cucumbers. Therefore, juveniles should be regularly transferred to new settling plates, sorted by size and injured individuals transferred to separate tanks. Light anaesthesia is usually used to reduce stress and facilitate handling of the sea cucumbers. *Microsetella* sp. (Ectinosomatidae) is commonly found in rearing tanks and can form large colonies in a short time, killing all the sea cucumber juveniles in 1–2 days when the situation gets out of control. Trichlorfon was formerly used to kill *Microsetella* sp., but the copepods have developed a strong resistance to this biocide and therefore have become difficult to eradicate. In 2003 a new and effective pesticide known as *Mei Zao Ling* was developed by the author. This product has little side effect on sea cucumbers.

Nursing of juvenile sea cucumbers: As the juveniles grow, the water quality and DO must be maintained at the optimal level. Increasing aeration and water exchange rates becomes necessary. The oxygen level has to be maintained above 5 mg/litre. It is also important to use formulated feed that can be digested and absorbed easily. Experimental results have shown that the growth rate of juveniles fed on the formulated feed is at least two times higher than that of individuals fed on traditional feed during the 20 to 30 day period. In recent years, studies on a series of formulated diets revealed that diet is a key factor for improving the survival and growth rates of juveniles in the nursing stage.

As the accumulation of excess food and faeces increases, harmful germs tend to multiply rapidly and can cause very serious disease outbreaks among juvenile sea cucumbers, including what is known as "stomach ulcer". Another disease is "white muscle syndrome", in which muscle tissues turn white and become rigid. More applied research is urgently required to find effective remedies to these problems.

Sea urchin

Broodstock management

Broodstock should be 3–4 years of age and 6–7 cm in test diameter. The shell of broodstock shouldn't be damaged. Photoperiod and water temperature are considered to be important in the control of reproductive maturation. Experimental broodstock cultivation has shown that multiple spawning is possible when well-fed sea urchins are cultivated in darkness in relatively warm water. So after being caught, the mature sea urchins are placed into dark tanks and reared with filtered seawater (8.0–15.5 °C and about 31.5 ‰ salinity). The density of broodstock is less than 20 sea urchins per m^2 and the sea urchins are fed with *Laminaria japonica*. Airstones are used to provide the oxygen to the broodstock. One half of the water in the tanks is changed daily, and every four days, all the water in the tank should be changed to remove any debris from the bottom.

Induction of spawning, fertilization and hatching

There are three ways to induce spawning:

- injection of 1–2 ml of 0.5M KCl solution easily induces mature sea urchins to spawn;
- putting the sea urchin in the shade and in running seawater; and
- removal of the mouthparts.

After spawning induction, the female and male sea urchins are placed separately into seawater to spawn. After enough eggs and sperm are released, the eggs are collected into a plastic barrel and mixed with some sperm to fertilize them. The quantity of the sperm is enough if there are 10–100 sperm around each egg.

The fertilized eggs hatch at 20–30 eggs/ml in the hatching barrel and rinsed of excess sperm once an hour. Before hatching, the water should be mixed twice an hour to avoid the fertilized eggs becoming deposited on the bottom of the barrel. The hatching temperature should be between 16 and 18 °C. After approximately 16 hours, the fertilized eggs will hatch.

Larvae rearing

Culture vessel: A pond (10–20 m^3) or aquarium (1.4 m^3) can be used as the culture vessel.

Planktonic microalgae for larviculture: Many species of cultured algae support rapid growth and development through metamorphosis. The planktonic microalgae's size, concentration, flavor and the stage of larval development will all influence larval feeding rate and microalgae selection.

The planktonic microalgae are reared at 15–30 °C and 7 000–10 000 Lux as measured by photometer. The nutrient salts included 5–20 mg $NaNO_3$, 0.5–1 mg KH_2PO_4 and 0.05–0.2 mg $Fe(NH_4)_3(C_6H_5O_7)_2$ in a 1000 ml volume. During the rearing process, the water should be maintained at a suitable quality and not polluted by other algae. After the density increases to 1 million cells/ml, it can be fed to the larvae.

Larvicuture management: After the blastulae float with little active movement at the surface of the water, the healthy larvae should be selected, the quantity estimated and the larvae transferred to the culture pond. The water should be changed twice daily, with half of the water each time,.

Larval development involves growth and elaboration of the larval body. After three to four days, the larvae have developed to the early pluteus stage, which requires planktonic microalgae as food. The four to eight-armed larvae should be fed with planktonic microalgae four times per day at 5 000–40 000 cells/ml/day.

The density is initially 1.0 larvae per ml, but decreases to 0.4–0.7 individuals per ml at the end of the eight-armed larval stage. The photometer should show a light level of less than 300 Lux. The salinity of the seawater is 30–31.5ppt, temperature is 16–18 °C, DO is 6.5–8.0mg/liter and pH is 7.9–8.3.

Benthic diatom cultivation and settlement

Settlement presents a variety of problems for echinoid larvae. Larvae must detect suitable habitat to switch from planktonic living to benthic living. Induction of settlement and metamorphosis occurs in response to environmental factors that signal the availability of suitable benthic habitat. A solution of 0.5M KCl can also be used to induce metamorphosis.

The attachment that induced the settlement uses polyvinyl chloride wavy plates (42x33 cm, each group having 20 plates) covered with the benthic diatom that serves as the food source for the juvenile sea urchin. The plates should be inoculated with the benthic diatom on both sides 20–30 days in advance of providing them to the sea urchins. Nutrient salts are added to stimulate algal growth. When the podium or thorn appears on the larvae, they should be put into the tanks with the plates covered with benthic diatoms. The larvae should be stocked at around 300–500 larvae per plate. The water in the tanks should be changed twice a day with half of the water removed at each time.

Early juvenile rearing

After all the larvae are metamorphosed, the sea urchins should be reared with continuous flow seawater to exchange water around three times per day (water flow of 100–500 percent). The photometer should indicate less than 3 000 Lux. The water should be aerated to provide enough oxygen for the sea urchin. Nutrient salts are added to the tanks every day to stimulate diatom growth. When the juveniles reach 2–3 mm in size, they should be transferred to the netcage and fed with *Ulva* sp. and *Laminaria japonica*.

Seaweed ***(Undaria pinnatifida)***

Undaria pinnatifida is the main seaweed species under cultivation in Dalian. The Dalian area contributes more than 80 percent of the yield from Chinese cultivation.

Collecting zoospores: Collection of zoospores begins in April to June when the plants become fertile. The matured sporophylls are kept in a dark, moist container for several hours to induce mass discharge of the spores. The spores attach themselves to the substrate and develop into male and female gametophytes.

Nursing of young sporelings: As young sporelings 3 to 5 cm long become overcrowded in their breeding station, they are moved to grow-out sites when seawater temperature drops below 20 ºC, e.g. around mid-October in northern China. The purpose of such a move is to stimulate their growth to a length of 10 to 25 cm before their transplantation. During this nursing period, young sporelings grow very rapidly.

Transplantation of young sporophytes: At the end of the nursing period, young seedlings are transplanted to kelp-culture ropes for final grow-out on floating rafts. The procedure is similar to the transplantation of young rice plants in paddy culture. The outgrowing of sporelings starts in the autumn when the water temperature is below 20 ºC.

GROWOUT METHODS

Several grow-out methods are being practiced in northern China.

Floating raft culture

There is a long history of using floating rafts for shallow-sea farming. This system can be used for a variety of species such as seaweeds (kelp and laver), filtering organisms (scallop, oyster, and mussel) and abalone, combined with culture in lantern cages.

The major advantages of this culture method are better growth rates and quality. The survival rate is also better when compared to bottom-culture methods, mainly due to the fact that bottom-dwelling predators (e.g. starfish and drills) are unable to reach the cultured oysters. However, with this method the rafts and cages can be easily damaged by storms and the cages fouled by a number of benthic organisms and seaweeds. The cages are periodically cleaned to avoid becoming blocked.

Pond culture

A high proportion of the area under cultivation is devoted to pond culture in marine and brackishwaters. Often, fishers culture shrimp, crab or marine finfish. Some benthic species such as Manila clam and razor clam are also cultured in the ponds. In recent years, pond culture of sea cucumber (*Apostichopus japonicus*) has developed in Liaoning and Shandong provinces, mainly centered in the Dalian area. The details are described below.

Optimal culture pond conditions

Pond size and water quality: Ponds are usually located in the intertidal zone for convenience of water exchange. The salinity should be maintained >28 ppt all year round, however, it can drop to 24–26 ppt over a short period in the summer. Water quality should remain high, and it can be renewed by opening and closing the sluice gates. The optimal pond size is usually 2–6 ha with a water depth maintained at 1.5–2.5 m.

Pond cleaning and sterilization: The best farming results are obtained in leak-proof ponds with a muddy sand substratum that requires sterilization prior to the rearing phase. This is done by first removing the bottom silt. At this point the pond is filled with seawater and the level adjusted to 0.2–0.3 m. Calcium oxide or bleaching powder is subsequently added.

Settlement substratum: According to the natural behaviour of the sea cucumber, the pond bottom requires a layer of adequate substratum for larval settlement to occur. Stones, roof tiles, bricks and other suitable structures can be used. The quantity of the substrate should be in the range of 150–1 500 m^3/ha, however, this can vary depending on the pond characteristics and production method employed. Stones remain the best choice, each of about 15–40 kg in weight. The settlement substratum should be added to the pond one month prior to the introduction of the sea cucumber juveniles.

Water conditioning: In order to ensure the right quantity of diatoms, the water should be inoculated at least 15 days before the juveniles are seeded. The most common fertilizer used is urea at about 30–60 kg/ha.

Juvenile rearing and growout

Growout season: The growout season can commence either in September/October or in March/April when the seawater temperature ranges between 10 and 15 °C. In a polyculture situation, the shrimp postlarvae are usually introduced in May-June.

Transportation of juveniles: The juveniles are placed in temperature-controlled boxes for transportation. They should not be fed for 1–2 days prior to this operation. The temperature should be maintained below 18 °C. The shrimp postlarvae are generally transported in oxygen-filled plastic bags with a sufficient quantity of seawater.

Juvenile size and rearing density: The juveniles may be from the wild or hatchery produced. Juveniles usually range between 2 and 10 cm in length, and their stocking density varies depending on the pond conditions, food supply and availability of settlement surfaces. The number of sea cucumber juveniles released is 15–40 individuals/m^2 for individuals measuring 2–5 cm, 15–25 individuals/m^2 for individuals of 5–10 cm, and 5–8 individuals/m^2 for individuals that are 10–15 cm in length.

There are two methods for releasing the juveniles. The first one is to place them on the sea bottom directly by hand or by simply releasing them from a boat using individuals larger than 4–5 cm. The second method, used when handling individuals smaller than 3 cm, is to place the juveniles in mesh bags with an opening at one end. The mesh bags are 30x25 cm in size and each one may contain up to 500 individuals. They are placed beside the settlement substratum.

The shrimp species used for polyculture with sea cucumber are the Chinese or Japanese shrimp species. The shrimp juveniles re usually 2–3 cm in length and are stocked at a density of 3–6 individuals/m^2.

Feeding: Sea cucumber juveniles usually do not require any additional food supply. However, the addition of food is necessary to maintain a high rearing density and to favour growth during spring and autumn. Ground pieces of *Sargassum* and *Zostera* are generally used.

Pond management: The seawater is renewed by opening and closing the sluice gates with the change of tide. About 10–60 percent of the total seawater should be exchanged depending on the water quality and temperature in the ponds. In summer, the water level in ponds should be kept higher in order to maintain a lower temperature. The salinity is maintained by regular water exchanges. The temperature, salinity, pH and DO levels should be monitored daily as well as the growth, survival rate and behaviour of the sea cucumbers.

During the winter months, the following additional tasks need to be performed:

- maintaining the water level at 2 m; and
- removing ice formations from the surface of the pond to keep the air-water interface free and ensure acceptable oxygen concentrations in the pond.

Harvest: The sea cucumbers are collected when they reach 150–200 g. Harvesting is done following drainage of the ponds or with the use of SCUBA. The shrimp are generally collected using nets placed at the sluice gates.

Mud flat culture

Mud flat culture is very popular in China because it does not require large quantities of food and it does not pollute the environment. This system is especially suitable for farming benthic species such as Manila clam (*Ruditapes philippinarum*), hard-shelled clam (*Meretrix meretrix*), blood cockle (*Tegillarca granosa*), razor clam (*Sinonovacula constricta*) and seaweeds such as *Porphyra* spp.

Net-cage culture

In China, marine fish farming entered a new era in the 1990s, following the great advances made on understanding the biology and rearing technologies of cultured species. The principal culture method for marine fish is net-cage culture. In northern China, the main species cultured are *Lateolabrax japonicus*, *Paralichthys olivaceus*, *Sciaenops ocellatus*, *Sebastodes fuscescens*, *Hexagrammos otakii* and *Fugu* sp.

Inshore cage culture is very popular world-wide, especially in China. Advantages include low investment and easy routine management. However, this system is one of the main sources of inshore pollution and a contributor to red tides. As most farmers use trash fish to feed high-value cultured fish, it does not take long before a great quantity of faeces and food residues accumulate on the sea floor and pollute the entire area. Another problem is that floating cages cannot resist strong winds and waves. The losses from such problems can be very serious.

Large-sized, current-resistant submerged netcages have been recently developed using fairly high-tech systems. These may help promote the sustainable development of marine fish farming. Meanwhile, mariculture using submerged cages has become a major aquaculture activity for utilizing the wider ocean for fish production.

Intensive indoor culture

This system is especially suitable for abalone and flounder culture. Abalone can be considered as one of the gastropods that have a high potential for commercial exploitation in the Asia-Pacific region. They command a high price and are highly relished in a number of Asian countries, particularly in China, Japan, the Republic of Korea and the Democratic People’s Republic of Korea. In this system, concrete tanks of around 3–50 m^3 are used. A dark PVC basket of 40x30x13 cm is commonly used, usually in a stack of 8–12 tiers arranged in rows in a tank. The baskets occupy 40–70 percent of the tank capacity. Fresh kelp, mostly *Laminaria japonica*, is the primary food during growout, and artificial diets are used when algae are not available. The major husbandry measures include adequate feeding, control of water flow, periodic elimination of abalone wastes and adjustment of the culture density. Usually this grow-out system has a high running cost, including the costs for pumping water, heating and aeration.

POLYCULTURE

Polyculture has a long history in freshwater aquaculture in China and could be applied more often in the marine environment. In marine polyculture, bivalves, seaweed and marine finfish are produced together. By using such complementary species, the wastes of one species can be converted to protein by the others. In finfish production, for example, feed that is not consumed filters down to suspension-feeding bivalves or mixes with faecal waste and is taken up by primary producers such as seaweed (harvested directly) or phytoplankton, which is then consumed by bivalves.

Bivalve and seaweed raft polyculture system

This form of culture shows much promise in increasing sustainability in many types of aquaculture, since it maintains a balance of nutrients in the environment and increases the efficiency of protein production.

In northern China, for example, kelps cultured on rafts provide shading, create sheltered areas less exposed to current flows, release oxygen as a product of photosynthesis and generally improve water fertility. Overall, *Laminaria* plants create a "mini-ecosystem" in otherwise open shallow seawater, making conditions more favourable for commercial production of scallops and other marine organisms. In turn, scallops and other cultured marine organisms in a polyculture system produce metabolic byproducts, especially dissolved N, P and CO_2, which act as natural fertilizers to meet the nutrient requirements of seaweed plants.

Polyculture in ponds

The main polyculture modes in ponds are shrimp-fish (e.g. mullet, tilapia, *Fugu* spp., perch, seabream and others), shrimp-sea cucumber, and shrimp-crab. The shrimp-fish system is the most successful. Some experts infer that there are two factors involved in the healthy growth of shrimp in the shrimp-fish system: predatory fish eat sick or morbid shrimp, thus reducing the spread of disease in the ponds; and there is an improved balance in the mini-ecology of shrimp ponds. Effluents rich in organic matter from shrimp culture can also be utilized by bivalves. Many species can filter out small particles and utilize microalgae from the effluent. These can be commercially valuable species for harvest or non-valuable species for use as fish-meal.

Another polyculture mode is crab-shrimp-bivalve, and this system is successful in Shandong and Jiangsu provinces; the crab is blue crab (*Callinectes sapidus*), the shrimps are *Penaeus chinensis*, *P. japonicus* or *Litopenaeus vannamei*; and the bivalves are *Ruditapes philippinarum*, *Argopecten irradians* or *Sinonovacula constricta.*

MARINE ENHANCEMENT

The capture fishery is unable to provide further increase to the total yield to meet the increasing demand for seafood for human consumption, particularly for the high-valued species that are either depleted or overfished. Thus the enhancement of fishery resources is an important measure that can be used to rebuild depleted stocks. Stock enhancement has been used for more than 20 years and has recently developed very quickly in China. The main species involved are high-value species as shown in Table 2.

TABLE 2
Aquatic species used in marine enhancement trials in northern China

Crustaceans	*Penaeus chinensis, P. japonicus, Litopenaeus vannamei*
Shellfish	*Patinopecten yessoensis, Haliotis discus hannai, Scapharca subcrenata, S. broughtonii*
Marine Fish	*Paralichthys olivaceus, Chelon haematocheila, Pagrus major, Pseudopleuronectes yokohamae, Larmichthys crocea, Acanthopagrus schlegelii schlegelii*
Echinoderms	*Stichopus japonicus, Strongylocentrotus intermedius S. nudus, Hemicentrotus pulcherrimus*
Jellyfish	*Rhopilema esculentum*

Shrimp

Penaeus chinensis is mainly distributed in the Bohai Sea and Yellow Sea. It has supported a very important fishery in the north. During 1985 to1992, 8.645 billion juvenile shrimp were released in the Bohai Sea. Shandong Province released 200 million juvenile shrimp into the waters around Shandong Peninsula in 2004.The recapture rate ranged from 0.001 percent to 1.88 percent.

Fish

Many fish species have been released into coastal waters in order to increase their stock size, but often intermittently, such as red seabream (*Pagrus major*), marbled flounder (*Pseudopleuronectes yokohamae*), So-iny mullet (*Chelon haematocheila*), black porgy (*Acanthopagrus schlegelii schlegelii*) and bastard halibut (*Paralichthys olivaceus*). Although the benefit is high, the input required is also high. In recent years, croceine croakers (*Larmichthys crocea*) have been released into the East China Sea to help rebuild the depleted stock.

Jellyfish

Following the depletion of some jellyfish fishing grounds, institutions in Liaoning, Shandong, Tianjin and Hebei started the experimental release of ephyra in the 1980s. Between 1994 and 2003, an average of 69.6 million ephyra were released annually into the bays around Shandong Peninsula by the province, resulting in an average catch of 4 994 tonnes per year. The abundance of jellyfish is closely related to environmental conditions; therefore, the economic benefit is highly variable. The recapture rate was 0.68–2.65 percent.

Shellfish and others

Seabed seeding is used to enhance shellfish and other resources, including scallop, clam, abalone, sea cucumber, trumpet shell, sea urchin, etc. This method is usually difficult to distinguish from mariculture, but it has the advantage of reducing disease compared with mariculture. The recapture rates for abalone and sea cucumber are much more predictable than that of shrimp. According to data recorded from commercial captures, the recapture rate for abalone may be as high as 50–70 percent. For sea cucumber, the rate depends more on site selection and improvement, with sheltered areas being more favourable.

In general, sea ranching is a good system to enhance or to re-establish a population that has declined, but numerous factors influence results. There is still a long way to go to reach the desired goals.

PROBLEMS AND SOLUTIONS IN MARICULTURE DEVELOPMENT

Major problems

There are three main limiting factors influencing mariculture development in China.

Seed quantity and quality

Two major constraints should be considered:

- Stable seed supply is not available for all major mariculture species.
- Mariculture seed available is not based on a good system of selective breeding and the genetic material available is still equivalent to the wild species. Selective breeding is needed to improve growth, disease-resistance and quality.

Many mariculture species have been or are being developed in China, the breeding techniques for most have been developed, and seed can be provided to farmers and cooperatives. However, relatively limited systematic research has been conducted on artificial selection and genetic improvement. This situation contrasts with investments in agriculture and livestock, and should be remedied.

Aquatic animal and plant diseases

In China the aquaculture industry developed quickly, and the variety of marine aquatic products has surpassed 40. The scale of cultivation also expands unceasingly and the output increases on a large scale. In the last few years, however, disease has occurred continually in aquaculture, with the country suffering economic losses of billions of Yuan every year. Shrimp disease losses have been serious since 1993. Fish disease, sea scallop disease, kelp disease, abalone disease and so on have occurred unceasingly. Improvements in disease control are, therefore, critical to future mariculture development in the region; and governments, researchers and farmers all have an important role to play.

Environmental pollution

The condition of the inshore sea environment has a close correlation with the mariculture industry. Along with fast social and economical development in coastal areas, massive amounts of industrial wastes and sewage are discharged into the nearshore without effective treatment. The result is that the water quality in the nearshore worsens gradually, with direct impacts on the survival and development of the mariculture industry. On the other hand, environmental pollution from mariculture is also noticeable. Because many farmers use poor-quality fish food, the food conversion ratio (FCR) is high and a large quantity of food is discharged, leading to harmful environmental pollution. The misuse and abuse of some antibiotics, disinfectants and water quality improvement medicines sometimes occurs, leading to other ecological impacts. In addition, the "irrational" layout of farms causes water quality problems, harmful algae and disease microorganisms, eventually harming the survival and development of mariculture.

Suggestions for continued development

Develop intensive cultivation and enhance output

In the twenty-first century, Chinese seawater cultivation will convert from extensive to intensive farming. Intensive cultivation has the virtues of high output, stable production, potentially minimal impacts on the environment if conducted efficiently, water saving and so on, with significant developmental potential.

Through the development of high-value cultured species, the seawater cultivation standard can be enhanced significantly. The present task is to develop modern aquaculture systems and technologies, such as new anti-storm cage techniques, economical and practical water treatments, automatic feeders, environmental monitoring, etc.

Application of biotechnology

The application of biotechnology in mariculture is a key issue, including the use of new species, gender control, germplasm preservation, disease prevention and control, etc. With the support of the hi-tech "863" project, Chinese researchers have obtained important breakthroughs in cellular engineering breeding techniques. Triploid and hybrid oyster, scallop and abalone; all-female prawn and flounder; and kelp, *wakame* and laver have been developed through hi-tech approaches and will soon enter the industrial stage. Biotechnology research should receive high priority in mariculture research and development.

Develop healthy aquaculture and prevent diseases

Reasonable farm layout, proper scientific management and developing healthy cultivation techniques and management are vital steps to prevent disease occurrence. Something must be done to optimize the ecological environment of the culture system and provide good survival for the cultivated species. Research on disease epidemiology should be strengthened to determine the ecology of the pathogens and to find ways to prevent their spread in the environment. Other areas that need to be addressed include immunity, technology and management practices for prevention and control of disease, and development of new medicines. Rapid examination and diagnostic systems should be established to enable early action to be taken and reduce the associated losses.

Feeds and feed management

The use of high quality feed enhances product quality, reduces cost and disease occurrence by minimizing water pollution and improves economic efficiency. Technical improvements in feed and feeding plays a major role in increasing the output value of aquaculture. The use of high quality feed is an indication of progress in aquaculture technology. Research on nutrition and feed development needs to catch up with the demand from a rapidly industrializing aquaculture sector. Most of the aquatic products rely on natural animal feed, which results in high cost, low efficiency and poor sanitation. To promote the healthy development of the mariculture industry, we should energetically develop artificial feeds with high quality, good stability, good attractability, good absorbency and low FCR.

Marine fish cage culture in China

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INTRODUCTION

Cage farming began in late 1970s in the People's Republic of China, originally introduced in inland aquaculture and later in mariculture. In the late 1970s, Huiyang County and Zhuhai City, Guangdong Province succeeded in farming marine fishes including grouper and seabream in cages. It was the first trial of marine cage farming in China. In 1981 experimental farming expanded to a commercial scale. Almost all of the products were exported to China, Hong Kong SAR and Macao markets. In 1984 other counties and provinces (Fujian, Zhejiang) began the farming of marine fish in cages. According to a survey, the number of marine fish cages in three provinces (Guangdong, Fujian and Zhejiang) has reached over 57 000. More than 40 species of marine fishes (Table 1) were farmed.

Cage farming was artisanal during the early stages of development. The research and development (R&D) for modern cage systems took place only beginning in the 1990s, primarily in line with the development of culture techniques for marine fishes like red seabream (*Pagrus major*), Japanese seaperch (*Lateolabrax japonicus*), cobia (*Rachycentron canadum*) and croceine croaker (*Larmichthys crocea*). Its development has been rapid since the start of this century. Hence, the history of offshore cage culture is less than ten years.

The most-farmed fishes are bred in land-based hatcheries enabling seed supply to meet the demand of cage culture. For example, last year one billion fingerlings of croceine croaker were bred in Fujian and Zhejiang provinces, with Fujian Province accounting for 70 percent. However, seed of some species still have to be captured from the wild or imported. These include yellowtail amberjack (*Seriola lalandei*), greasy grouper (*Epinephelus tauvina*) and others.

The total number of marine cages of different models has reached one million. The marine cages are distributed along China's coastal provinces – Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan provinces, and the Guangxi Zhuangzu Autonomous Region. About 3 000 are offshore cages. The output from cage culture was about 200 000 tonnes in 2005.

Inshore cage culture is facing three problems:

- there is not enough space for further expansion;
- the cages cannot withstand typhoons, so that the security of fishermen's lives and property is threatened by this annual disaster; and
- inshore cage farming causes severe environmental pollution through fish metabolites and residuals (e.g. trash fish), inducing outbreaks of disease and parasitic infections. Thus offshore cage culture promises to be a better option.

TABLE 1
Economically important fishes reproduced in hatcheries in China

Chinese name	English name	Scientific name	Origin
鲻[1]	Flathead mullet	*Mugil cephalus*	Native
梭鱼[1]	So-iuy mullet	*Mugil soiuy*	Native
鲈鱼[1]	Japanese seaperch	*Lateolabrax japonicus*	Native
遮目鱼/虱目鱼	Milkfish	*Chanos chanos*	Native
军曹鱼，海鲡	Cobia	*Rachycentron canadum*	Native
尖吻鲈[2]	Barramundi	*Lates calcarifer*	Native
赤点石斑鱼[1]	Hong Kong grouper	*Epinephelus akaara*	Native
青石斑鱼[1]	Yellow grouper	*E. awoara*	Native
锐首拟石斑鱼 (驼背鲈/老鼠斑)	Humpback grouper	*Cromileptes altivelis*	Native & introduced from Malaysia
大黄鱼[1]	Croceine croaker	*Lamichthys crocea*	Native
鮸状黄姑鱼	Amoy croaker	*Argosomus amoyensis*	Native
眼斑拟石首鱼 [1,2] (美国红鱼)	Red drum	*Sciaenops ocellatus*	Introduced from USA
真鲷[1]	Red seabream	*Pagrus major*	
黑鲷	Black seabream	*Acanthopagrus schlegelii schlegelii*	Native
平鲷	Goldlined seabream	*Rhabdosargus sarba*	Native
笛鲷	Snappers	*Lutjanus* spp.	Native
胡椒鲷	Sweetlip	*Plectorhynchus* spp.	Native
大泷六线鱼	Fat greenling	*Hexagrammos otaki*	Native
黑平鲉	Black rockfish	*Sebastes pachycephalus nigricans*	Native
牙鲆[1]	Bastard halibut	*Paralichthys olivaceus*	Native
漠斑牙鲆[2] (南方鲆)	Southern flounder	*Paralichthys lethostigma*	Introduced from USA
夏鲆[2]	Summer flounder	*Paralichthys dentatus*	Introduced from USA
石鲽	Stone flounder	*Kareius bicoloratus*	Native
黄盖鲽	Marbled sole	*Pseudopleuronectes yokohamae*	Native
大菱鲆[1,2]	Turbot	*Psetta maxima*	Introduced
半滑舌鳎	Tongue sole	*Cynoglossus semilaevis*	Native
红鳍东方鲀[1]	Torafugu	*Takifugu rubripes*	Native & introduced from Japan

[1] Main cultured species raised on large commercial scale.
[2] Exotic species introduced from other countries & zones.

Developing offshore cage farming is a new way to provide employment for people switching from fishing to aquaculture. From 2003 to 2010, an estimated 300 000 fishers are expected to leave their boats and look for other jobs. Offshore cage farming creates an opportunity for them.

The Chinese government and relevant authorities strongly support the development of offshore cage farming, both in policy and financing. Since the beginning of the twenty-first century, six types of offshore cages have been developed and extended in coastal provinces. They are the HDPE circle cage, the metal frame cage, the floating rope cage, the dish-formed submersible cage, the PDW submersible cage and the SLW rotatable and submersible cage. Developing offshore cage farming can create significant socio-economic impacts. The short-term target of offshore cage culture is that marine fish farming will become a major sector in China's aquaculture industry. The projected output of cultured marine fishes is around 500 000 tonnes by 2010.

PRESENT STATUS OF MARINE CAGE CULTURE

Traditional cages

Configuration, model, quantity and distribution

Traditional cages still account for the majority of marine cages. The total quantity is about one million, distributed along the coastal provinces of China. These cages are at an artisanal level; the configuration and the design are small (normally 3x3 m to 5x5 m in size, with nets of 4–5 m in depth), simple (square in form) and rough (Figure 1). The materials used for these cages are collected from the local market and include bamboo, wooden boards, steel pipes and polyvinyl chloride (PVC) or nylon nets. Most inshore cages are made by the farmers themselves to save investment cost and are easy to manipulate. These cages, however, cannot withstand waves and winds caused by typhoons and swift sea-currents; they have to be installed in inshore waters and sheltered sites. In some locations, the cages are connected together to form a big floating raft and crowded into small inner bays (Figure 2).

FIGURE 1
Traditional cages, simple and roughly constructed

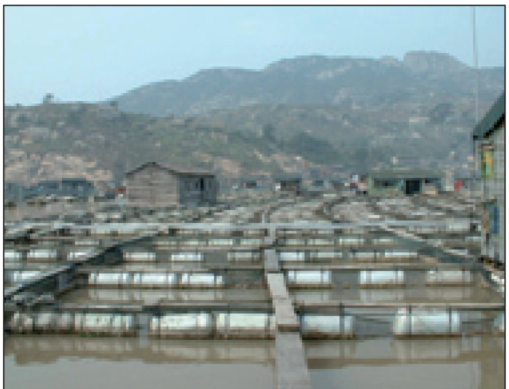


FIGURE 2
Shallow fish cages crowded in inshore waters

Most of the cages are distributed in Fujian, Guangdong and Zhejiang provinces, which account for 80 percent of total number of marine cages in China (Table 2).

TABLE 2
Number and distribution of traditional cages

Year	Location	Number of cages
1993	Guangdong, Fujian, Zhejiang	57 000
1998	All coastal provinces	200 000
2000	All coastal provinces	Over 700 000[1]
2004		1 000 000
Distribution:	Fujian	540 000
	Guangdong	150 000
	Zhejiang	100 000
	Shandong	70 000
	Hainan	50 000
	Other provinces & zones	100 000

[1] Of which 450 000 in Fujian Province

The reasons for rapid extension

Along with the Chinese open door policy, economic development has stimulated the demand for aquatic products, especially live marine fishes. The soaring price of marine fish in the 1990s further accelerated the extension of marine cage culture. Figures 1 and 2 show a farm located in Luoyuan Bay, Fujian Province. In 1990 there were less than 1 000 cages in the bay, but during the highest period (late 1990s), the number of cages in this area reached 60 000. At that time, the price of farmed live marine fish such as red seabream was about US$6 per kg with a production cost of only US$2 per kg and thus a profit margin of 200 percent. No doubt this high profit margin was one of the main factors expediting the expansion. It is a typical example showing the development of inshore cage farming in China.

Problems with traditional cages

As traditional cages cannot withstand high waves and winds caused by typhoons and fast currents, they have to be installed in inshore waters or sheltered sites. A lot of cages in inshore waters cause problems, the foremost of these being pollution caused by metabolites of fish and residual feed. With a series of cages blocking the inner bay, the reduced current and water exchange will lead to metabolites and residual feed accumulating on the seabed. One investigation showed that the accumulated waste in some severely affected locations was as high as one meter or more. Eutrophication, disease outbreaks and lower quality of farmed fish are the result, while poor seawater quality jeopardizes other farmed animals like oyster and scallop and may cause occurrences of red tide. The losses caused by diseases and red tides have been placed at US$10 million annually. In addition, the vulnerability to typhoons causes severe economic loss. For example, the direct financial losses caused by typhoon "Chebi" on Fujian Province in 2001 reached US$150 million.

Facing up to this severe situation, China's government and relevant authorities have actively encouraged farmers and investors to develop offshore cages. Beginning in the late 1990s, offshore cages have been introduced from developed countries including Norway, the United States of America and Japan, while R&D of offshore cages has started in coastal provinces including Shandong, Zhejiang, Fujian and Guangdong. At present, there are about six types of offshore cages developed and installed in all coastal provinces and zones. The experiences suggest that some offshore cages can withstand typhoons, increase the output of fish with higher commercial value and minimize pollution, as well as gain higher income for fishermen.

The present direction in China is towards offshore cage culture becoming a main form of marine culture in the near future, while inshore cages will be used for nursing to supply large fingerlings for stocking into offshore cages or release into the open sea for sea ranching.

DEVELOPMENT OF OFFSHORE MARICULTURE CAGES

The development of offshore cages in China was initiated in the late 1990s. In 1998 the first offshore cages (four cages, 40 m and 50 m in perimeter) were introduced into Hainan Province from Norwegian Refa Fiskeredskap AS. Another 32 offshore cages have been introduced from different countries and installed in coastal provinces including Shandong, Zhejiang, Guangdong and Fujian since 2000. From then on, developing and extending offshore cages have been confirmed as a priority of marine fish farming by the Chinese government and relevant authorities.

Importance of developing mariculture

China has a population of more than 1.3 billion, and its land natural resources per capita are lower than the world's average. Official statistical data show that China has a land area of 9.6 million km^2, making it the third biggest country in the world. However, the land area per capita is only 0.008 km^2, much lower than the world average of 0.3 km^2 per capita. The cultivated area per capita in China is only 7 percent of the world total. It is estimated that the demand for grain and other food will reach 160 million tonnes by 2030. As a major developing country with a long coastline, China is facing up to the serious fact that it must take exploitation and protection of the ocean as a long-term strategic task before it can achieve sustainable development of its national economy.

In developing its oceanic fishing industry, China adheres to the principle of "speeding up the development of aquaculture, purposely conserving and rationally utilizing offshore resources" and is actively expanding offshore aquaculture. Since the mid-1980s, China's mariculture has rapidly developed, with a large increase in species and expansion of breeding areas. In accordance with the actual conditions of marine fisheries resources, China has actively readjusted the structure of this sector and made efforts to conserve and rationally utilize off-shore space, so as to make the mariculture industry constantly adapt to the changes in the marine fisheries structure.

Since the 1990s, the Chinese government has been carrying out a series of comprehensive reforms and new policies in the fishery sector, the following of which are relevant to mariculture:

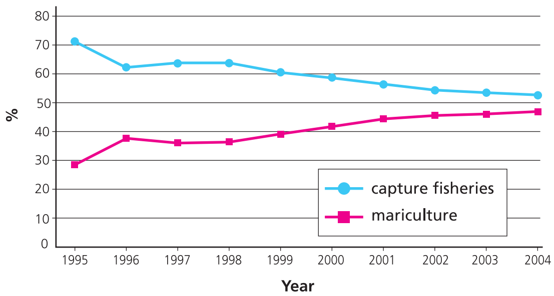
- Since 1995, China has practiced a midsummer moratorium system. Every year during July and August fishing is banned in the sea areas north of 27°N latitude. The new system has achieved encouraging economic, ecological and social results, and as of this year the midsummer moratorium area will be expanded to 26°N latitude and its duration will be lengthened to three months.
- A policy of carrying out "zero gain" of marine capture fisheries from 1999, and putting "minus gain" into practice in future years will be implemented.
- A total of 30 000 fishing vessels of various types will be removed from the fishery between 2003 and 2010; and more than 200 000 fishermen will have to leave their fishing vessels and obtain new jobs, including work in the mariculture subsector.

The purpose in implementing these new policies is to establish sustainable fisheries through protecting marine resources and by means of mariculture and sea ranching. The performance so far has been significant; for example, the landing volume from the sea was 2.356 million tonnes in 1995, among which the output from mariculture accounted for only 28.7 percent (4.1 million tonnes). However, this situation has been gradually changed; the proportion derived from marine culture has continuously increased such that the landing volume from mariculture reached 47.6 percent (13.1 million tonnes) in 2004 (Table 3 and Figure 3). It is believed that mariculture will become the major contributor to total marine output in the near future. The gain from the marine fishery will shift from marine capture to mariculture. Developing offshore cages has consequentially become a priority project of the Chinese government and investors.

TABLE 3
The proportion of mariculture and marine capture in the total output of marine fisheries in China, 1995–2004

Year	Total output of marine fisheries	Marine capture		Mariculture	
		Output	% of total marine fisheries output	Output	% of total marine fisheries output
1995	14 391 297	10 268 373	71.3	4 122 924	28.7
1996	20 128 785	12 489 772	62.0	7 639 013	38.0
1997	21 764 233	13 853 804	63.6	7 910 429	36.4
1998	23 567 168	14 966 765	63.5	8 600 403	36.5
1999	24 719 200	14 976 200	60.5	9 743 000	39.5
2000	25 387 389	14 774 524	58.2	10 612 865	41.8
2001	25 721 467	14 406 144	56.0	11 315 323	44.0
2002	26 463 371	14 334 934	54.2	12 128 437	45.8
2003	26 856 182	14 323 121	53.3	12 533 061	46.7
2004	27 677 900	14 510 900	52.4	13 167 000	47.6

Figure 3
Proportion change between marine capture fisheries and mariculture, 1995–2004



Government financial support

Developing offshore cage culture needs high investment and entails high financial risk. Individual farmers are hardly able to bear the expenses for developing offshore cages and the risk. The Chinese government and the provincial authorities therefore strongly support the project. It is estimated that the investments from different sources have reached more than US$10 million. For example, 20 projects dealing with offshore cages have been granted and have obtained as much as 20 million Yuan in financial support in the last five years. In addition, since 2001, Zhejiang, Fujian, Guangdong, and Shandong provinces have arranged special funds (more than 50 million Yuan) for developing offshore cages. The funds are partially for R&D, while directly supporting fishermen to buy offshore cages. This financial support and favourable policies promote the development and extension of offshore cage culture.

TABLE 4
Quantity and distribution of offshore cages in China[1]

Model	Zhejiang[2]	Shandong	Fujian	Guangdong	Other provinces	Total
HDPE circle	640	495	488	60	100	1 800
Floating rope	1 083	-	-	150	-	1 300
Dish-formed submersible	13	-	-	-	-	13
Other	51	110	-	-	100	180
Total	1 787	605	488	210	200	3 293

[1] Cage volume: >500 m^3.
[2] The figure for Zhejiang Province is from the first half of 2004; data for other provinces are the latest available.

According to incomplete survey data, about 3 300 offshore cages of different models have been installed in the coastal provinces, of which 1 800 are plastic hose (high-density polyethylene, HDPE) circle cages (floating and submersible) distributed in Zhejiang, Shandong, Fujian and Guangdong provinces and another 1 300 are floating rope cages installed in Zhejiang, Guangdong and Hainan provinces (Table 4).

Models and features of offshore cages

There are six offshore cage models developed. They are:

- HDPE floating circle cage (Figure 4a and 4b);
- Metal frame gravity cage (Figure 5);
- Floating rope cage (Figure 6);
- Dish-shape submersible cage (Figure 7);
- PDW submersible cage (Figure 8); and
- SLW submersible cage (Figure 9).

High-density polyethylene (HDPE) floating circle cage

The HDPE cage is based on the Norwegian design that was introduced into China (Figure 4). It is simple and easy to manufacture, and relatively low cost compared to others. The results indicate that although these cages cannot withstand typhoons, they are much better than traditional cages. The cage consists of net frame, nets, and anchoring system. The frame is made of high-density polyethylene (HDPE) and the nets are made of nylon. The cage performs well in the open sea with 20–40 m water depth. For example, in 2003 two cages were used to farm Japanese perch (*Lateolabrax japonicus*) and rockfish (*Sebastes schlegelii*). The stocking density of both species was 10 000 fingerlings (10 fingerlings per m^3) per cage. The survival rate was more than 80 percent after one-year grow out; the harvest reached 4–5 tonnes for each species. Although this is not high enough, the higher survival rate, the reduced use of chemicals and the lower energy costs meet the demands of farmers. The disadvantage of this type of cage is its lower ability to resist water currents. When the current velocity reaches 0.5 m/sec, the nets will swing up and down; at 1.0 m/sec, the effective volume of the cage will be reduced by 60 percent. This seriously influences the cage safety and causes stress to farmed fish. Technical parameters of the HDPE cage are listed in Table 5.

FIGURE 4a
HDPE floating circle cage

FIGURE 4b
Inauguration of a HDPE floating cage

The first kind of cage cannot withstand typhoons; therefore, submersible cages have been devised for installation at sites subject to typhoons. The basic structure is similar, except that before a typhoon arrives it can be submerged 4–10 m beneath the sea surface within 8–15 min, and it is easy to refloat it to the surface within 3–13 min after the typhoon has passed.

The cage can be installed in the open sea of 15 m depth and thus is suitable for China's shallow sea. Importantly its cost, which is about US$15 per m^3 (effective volume inside of cage), is about 40 percent that of imported cages.

TABLE 5
Technical parameters of the HDPE cage[1]

Model	Circumference (m)	Capacity against wind (km/hr)	Capacity against wave height	Capacity against sea current (m/sec)
HDPE 30	30	60–100	4	1.0
HDPE 40	40	60–100	4	1.0
HDPE 50	50	60–100	4	1.0
HDPE 60	60	60–100	4	1.0

[1] Diameter of HDPE pipe: φ200~φ315mm; density of HDPE: φ=0.95g/cm^3, intensity of HDPE: $φ_s$ = 24MPa.

Metal frame gravity cage

Metal frame gravity cages have various forms, such as rectangular or circular, and may be floating or submersible (Figure 5). Except for the cage material used, which is different from that used for the HDPE cage, the basic principle is the same. Between 2003 and 2004, two companies in Zhejiang Province introduced these cages from Japan. Their use in the open sea proved that the performance of the metal cage in swift currents is good, but that the metal nets are easily eroded by seawater. There are now about 30 metal cages (10x10x8 m) installed in the province.

FIGURE 5
Metal frame gravity cage

FIGURE 6
Floating rope cage

Floating rope cage

The floating rope cage was adopted from Japan in the 1970s and used by farmers in Taiwan Province of China. Since the 1990s, these cages have become widely used in Hainan, Guangdong and Zhejiang provinces (Figure 6).

It is a simple offshore cage that can also be used in inshore waters. It has a good capacity against strong winds (60–100 km/hr) and a lower cost that is welcomed by farmers. The size of a single cage is 6x6x6 m, and the total cage area can reach 1 000–2 400 m^3 when cages are linked together. The interval between two cages is 3 m.

The first attempt to farm cobia in Hainan Province was successful. A total of 11 871 fingerlings (0.75–1.0 kg/fish) were stocked in two cages. After four months, 8.6 tonnes of fish were harvested from the two cages. The largest fish to be harvested had gained 5.5 kg and was 80 cm in body length, while the smallest weighed 3.2 kg and measured 68 cm. The production cost was US$3.5/kg and the profit margin was US$2/kg.

Dish-shaped cage

The dish-shaped cage, which is similar to the "sea station" as it is called in the United States of America, was introduced from Ocean Spar Technologies in 2002 and installed in Shengsi County, Zhejiang Province (Figure 7). The "Ocean Station" is utilized in areas with high seawater current velocities. The design of this cage ensures little reduction of cage volume with current, and it can be submerged below the surface. It is shaped like a double cone with a central spar, and is equipped with variable buoyancy chambers and dead weights so that it may be actively submerged in rough weather and brought back to the surface later for normal operation. Three years of practice indicates that the cage introduced from the United States of America is excellent against typhoons and high current velocities, but a crucial shortcoming is that its design makes it difficult to harvest the farmed fish. A new model of dish-formed cage that was devised by a Zhejiang company is welcomed by Chinese cage farmers in Zhejiang Province.

FIGURE 7
Dish-shaped cage
(made in Zhejiang Province, China)

PDW submersible cage

All cages mentioned above were introduced from other countries. However, the PDW cage was developed in China as independent intellectual property (Figure 8). The PDW submersible cage is specially designed for flatfish farming. Flatfishes such as flounder, sole, turbot and halibut have a high commercial value in international and domestic markets and are popular farmed fish in China. Normally they are cultured in indoor cement tanks and/or fiberglass containers with seawater that has to be pumped from the open sea. Hence, the production cost is much higher than that of cages. However, most of the cages mentioned above are not suited to the ecological habits of flatfishes, so the PDW submersible cage was designed for this special purpose.

In normal conditions it is submerged on the seabed. During maintenance, net exchange and harvesting, it can be floated to the surface; and it is thus easy for these operations. In order to provide a stable environment for farmed fish, the cage nets are held tight, providing a good habitat for flatfish. At the same time, the cage is separated into multiple-layers that increase the effective space for flatfish.

The experiences in Yantai Fisheries Research Institute, Shandong Province, have shown that the cage is good for farming flatfish (flounder and turbot). Founder fingerlings (*Paralichthys olivaceus* and *P. lethostigma*) of 50–100 g (live weight) were stocked; after six to eight months the body weight reached 800–1 000 g at a stocking density of 20 fish per m^2. During the experimental period, the cage withstood a typhoon attack with 90–100 km/hr wind velocity, 5 m wave height and 1 m/sec current velocity. The cage possesses strong ability against swift currents and waves due to being submerged on the seabed (Table 6).

TABLE 6
Technical parameters of the PDW submersible cage

Model	Effective surface range (m^2)	Diameter (m)	Ability against wave height (m)/ wind speed (km/hr)	Ability against seacurrent (m/sec)
PDW 200	200, 260	12	5/100	1.2
PDW 280	280, 380	14.5	5–7/100	1.2
PDW 350	350, 460, 550	16.5	5–7/100	1.5

FIGURE 8
PDW submersible cage, manufactured by Fishery Machinery and Instrument Research Institute (FMIRI), Shanghai, China

FIGURE 9
SLW submersible cage manufactured by Fishery Machinery and Instrument Research Institute (FMIRI), Shanghai, China

SLW cage

The SLW cage's special design is adaptable to the direction of current and to swift currents (Figure 9). Its technical parameters are given in Table 7. Its features include:

- one anchor fixed on the seabed always faces up to the current direction;
- easily moved to a new position for anchoring;
- strong capacity against current; when current speed reaches 1.5 m/sec, its effective volume is 95 percent or more; and
- a cage body that can run like a wheel, preventing bio-fouling and allowing easy exchange of nets.

TABLE 7
Technical parameters of the SLW submersible cage

Model	Effective surface (m^2)	Length x diameter (m)	Capacity against wave height (m)/wind speed) (km/hr)	Capacity against seacurrent (m/sec)
SLW 400	400	16 x 6.5	5/100	1.5
SLW 1000	1 000	20 x 10	5/100	1.5
SLW 2000	2 000	25 x 12.5	5–7/100	1.5

The characteristics of all offshore cages discussed above are shown below in Table 8.

TABLE 8
Summary of the characteristics of different offshore cages

Item	FRC[1]	HDPE	MFC	DSC	PDW	SLW
Anti-wind (grade)	12	12	12	12	12	12
Anti-wave (m)	7	5	5	7	6	7
Anti-current (m/sec)	≤0.5/0.5	≤1/0.5	≤1/0.8	≤1.5/1.7	≤1.0/1.2	≤1.5/1.7
Frame material	PP, PE	HDPE	steel	steel	steel	steel
Site installed	semi-open	semi-open	inshore	offshore	semi-open	offshore
Installation	easy	easy	easy	laboured	easy	laboured
Maintenance	laboured	easy	easy	laboured	easy	laboured
Harvesting	easy	easy	easy	laboured	easy	laboured
Suitable fishes	pelagic	pelagic	pelagic	pelagic	benthic	pelagic
Cost	low	medium	medium	high	medium	high

[1] FRC: floating rope cage, HDPE: HDPE circle cage, MFC: metal frame cage, DSC: dish-shaped cage, PDW: PDW submersible cage, SLW: SLW submersible cage.

Development of associated facilities

Offshore cage culture is a complex system that involves much equipment, such as that for grading, harvesting, feeding, net-cleaning and maintenance, live-fish transportation, auto-monitoring and others. China's offshore cage farming is in a fledgling stage so that many operations can be considered as pilot activities. It is expected that offshore cage farming will also develop the input supply and equipment industries. There will be a big market for fishery facility manufacturers.

Fish species farmed in cages

There are about 30 species (Table 9) of fish to be farmed both in traditional and in offshore cages, but the prices of farmed fish differ between those farmed in inshore cages and offshore cages. The quality of fish flesh from offshore cages is much better than that from inshore cages. For example, the price of croceine croaker farmed in offshore cages is about US$8 or more per kilogram, which is almost double the price of the fish farmed in inshore cages. Thus, the return from offshore cage farming is much better than that from inshore cages.

TABLE 9
Economically important fishes farmed in cages

Species	Farmed region	
	Northern	Southern
Croceine croaker *(Larmichthys crocea)*		√
Red drum *(Sciaenops ocellatus)*		√
Cobia *(Rachycentron canadum)*		√
Grouper *(Epinephelus* spp.*)*		√
Japanese seaperch *(Lateolabrax japonicus)*	√	√
Rock fish *(Sebastodes fuscescens)*	√	
Fat greenling *(Hexagrammos otakii)*	√	
Red seabream *(Pagrus major)*	√	√
Black porgy *(Acanthopagrus schlegelii schelgelii)*	√	√
Derbio *(Trachinotus ovatus)*		√
Torafugu *(Takifugu rubripes)*	√	
Bastard halibut *(Paralichthys olivaceus)*	√	
Southern flounder *(Paralichthys lethostigma)*	√	√
Tongue sole *(Cynoglossus semilaevis)*	√	√
Turbot *(Psetta maxima)*	√	

Among the species grown in offshore cages are the croceine croaker, which is mainly farmed in Zhejiang and Fujian provinces, cobia and grouper which are raised in Hainan and Guangdong provinces, and some other species (torafugu, red seabream, red drum, etc.) that are bred in Shandong Province in the north and Fujian Province in the south of China. Notwithstanding the large number of marine species, it is difficult to select one or two candidates suitable for growing in northern provinces like Shandong, Liaoning and Hebei year round because the seawater temperature of these provinces is quite low in winter (around 1–2 °C) and quite high in summer (26 °C or higher). The wide fluctuation in seawater temperature makes it difficult for certain species. For example, in the northern provinces most farmed fishes cannot be farmed over winter in the open sea and must be moved to indoor tanks if they cannot attain commercial size. In this case, genetic improvement is a priority project for developing cage farming.

TECHNICAL ISSUES IN DEVELOPING OFFSHORE CAGES

The history of developing offshore cages is less than ten years. As a young industry, there remain many technical issues to be resolved. These include:

- increasing the ability of cages to withstand strong seacurrents and retain their effective volume;
- developing cages that are better suited to the sea conditions in different regions and to different species, for example, in the north for flatfish and in the south for croceine croaker, cobia and grouper;
- producing associated facilities and equipment, including machines for feeding, grading, net-cleaning, auto-monitoring, antifouling, harvesting, etc.;
- studying new antifouling compounds to replace imported compounds for which the cost is too high to be accepted by farmers;
- developing stronger artificial fibers like super-high molecule polyethylene for stronger cage-nets;
- developing effective formulated feed to replace the trash fish that is still widely used in some cage-farming zones (Figure 10), causing water pollution and waste of aquatic animal protein (formulated feed has been used in aquaculture for 30 years, but is not widely used in marine cage culture);
- implementing healthy farming practices as a priority project in China, including the urgent development of vaccines; and
- breeding new varieties that are suitable to offshore cage farming.

FIGURE 10
Farmer carrying trash fish used for feeding farmed fish

GOVERNMENT POLICY FOR DEVELOPING CAGE CULTURE

It is a priority to develop offshore cage farming in Chinese mariculture. For example, Shandong, Zhejiang and Guangdong provinces have plans to install 10 000 offshore cages inside the 40m isobath; Fujian and Hainan will have 5 000 cages each by 2010; while Liaoning, Hebai, Jiangsu and Guangxi provinces are also planning to increase the number of offshore cages in the near future. By 2010 the total quantity of fish landed from offshore cages is projected to reach about 500 000 tonnes; and some 100 000 people will be employed in offshore cage farming.

Offshore cage farming is an important source of employment for fishermen who have been transferred from fishing to other jobs. China's capture fisheries resources have been declining, and according to conventions between China and the Republic of Korea, China and Japan, and China and Viet Nam, about 30 000 fishing vessels have to leave their traditional fishing grounds. Therefore, about 300 000 fishermen will have to be gradually transferred to other jobs from 2003 to 2010.

Promoting sustainable development of the fishery industry is a strategic move. Rationally exploiting the offshore zone (inside the 40m isobath) is important because there is no room for further development in inshore waters.

It is necessary to meet the demand of an increasing population. In 2030 the Chinese population will reach 1.6 billion. In accordance with the consumption level of 38.7 kg per capita in 2004, the additional requirement for fisheries production will be 1.16 million tonnes. Furthermore, the world market needs more quality fish. Therefore, developing offshore cage farming is an effective way to achieve the two goals of maintaining per capita consumption and earning money from exports. Experts estimate that by 2035, the global output from aquaculture will reach only 62 million tonnes. If a 1 percent increase in consumption is assumed, the demand would be 124 million tonnes. FAO reports that the landed volume of marine fish from mariculture is only 4 percent of the total volume of fisheries. In this regard, there is an increasing demand for marine fish, not only in domestic markets but in the global market as well. Developing offshore cage farming is, therefore, an answer to meet this demand.

MANAGEMENT OF OFFSHORE CAGE CULTURE

Routine management starts from stocking and requires daily observation. Management includes feeding, grading, cleaning or exchanging fouled nets and routine recording. Paying attention to routine management guarantees a good result. Management of offshore cage culture should give attention to the following aspects.

Site selection for offshore cage farming

The site for offshore cage farming should meet the following conditions:

- a depth of more than 10 m and less than 30 m;
- a seabed that is plain, open tideway, mud-sandy substratum or rocky bottom;
- a current velocity of 50–100 cm/sec;
- a seawater surface temperature of 8–28 ^{o}C (optimum temperature is 18–26 ^{o}C);
- a pH of 7.8–8.6;
- DO of >5 mg/liter;
- transparency of >50 cm; and
- other conditions in accordance with seawater standards for fishery.

Cage layout

- The acreage of offshore cages should be less than 10 percent of the total farming area.
- The direction of cage layout should correspond to the direction of the sea-current.
- The arrangement of cages should be that two groups of cages are installed in parallel; the interval between the two groups is 80–100 m and the interval between the two lines of cages should be more than 50 m.

Species selection

- Candidate species for offshore cage farming should have basic requirements that match the conditions of the receiving environment (e.g. seawater temperature, salinity);
- Fingerlings should be quarantined before stocking (specific pathogen free (SPF) and healthy fingerlings are needed);
- The seed should come from qualified hatcheries and possess good genetic characteristics.

Stocking requirements for fingerlings

- The fingerlings should be healthy and vigorous.
- They should be free from parasites and other diseases.
- They should be graded for size and consistent weight (a weight per fingerling of more than 100 g will guarantee the survival rate and grow-out to commercial size during the culture season).
- The stocking density should be 30–50 individuals per m^3 or 20 fingerlings per m^2 for flatfishes (yield is about 20 kg/m^3 depending on species).

Feed and feeding

- Feed is a vital factor; trash fish has been used in large quantities because it is cheap and easy to buy in local markets; however, it is a source of disease. Normally, the food conversion ratio (FCR) is about 6 to 8 if using trashfish.

- It is a priority to develop high-quality formulated feeds.
- Automatic feeding systems are not widely adopted; judgment of feeding requirements based on visual observation is common at most farms. Normal feeding frequency is one to three times per day, the quantity fed depending on ambient conditions such as temperature, current, turbidity, waves, etc.

SOCIAL AND ECONOMIC IMPACTS OF OFFSHORE CAGE FARMING

Developing offshore cage farming has created social and economic impacts.

- There is a need to expand the space used for mariculture without occupying precious land and consuming freshwater.
- The eutrophication of seawater and the release of pollutants harmful to the environment and to the farmed fish themselves need to be reduced so that offshore cage farming is an environmental friendly system.
- The improvement of design and materials used in cages greatly increase their abilities to withstand typhoon and swift currents (Table 10). Hence the security of marine cage farming has reached a new level that brings improved benefits to farmers and investors.
- The development of offshore cage culture augments the employment for fishermen who have lost jobs in the capture fishery.
- Developing offshore cage culture brings new opportunities for the manufacture of offshore cages and equipment for monitoring, grading, feeding, etc.

TABLE 10
Comparison of economic effect between inshore and offshore cage culture

Items	Traditional cage culture	Offshore cage culture
Survival rate of fish (%)	70%	> 90%
Cage volume (m^3)	< 100	> 1000
Capacity against wind (km/hr)	< 100	> 110
Capacity against current (m/sec)	< 1	< 1.5
Capacity against wave-height (m)	2	> 6
Life span of cage (year)	< 3	> 10
Sea site suitable the cage	Inshore/sheltered only	offshore
Yield (kg/m^2)	about 5	> 20
Ratio of input vs output	1:1.3–1.5	1:1.5–2.0

This review finishes with the words published in the "White Paper on the Development of China's Marine Programmes" issued in 1998 by the Information Office of the State Council of the People's Republic of China:

"China has put the issue of rational utilization and protection of marine resources and the marine environment into the overall, cross-century plans for national economic and social development, and has adopted the sustainable development of marine programmes as a basic strategy. With the continuing growth of the forces of social production, the further building-up of comprehensive national strength and the gradual awakening of the people's consciousness of the importance of marine protection, China's marine programmes will definitely enjoy still greater development. Together with other countries and international organizations concerned, China will, as always, play its part in bringing mankind's work for marine development and protection onto the road of sustainable development."

Developing marine cage farming is a long-term strategy in terms of mariculture; therefore, the increased attention to its development will continue for many years. Its social effects and environmental impacts will be far-reaching. Beyond all doubt, it is indispensable to consider how to improve the existing situation to make rational layout and scientific decision-making that will ensure a sustainable mariculture in China as well as for the world's fisheries.

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Development of seafarming in India – an export perspective

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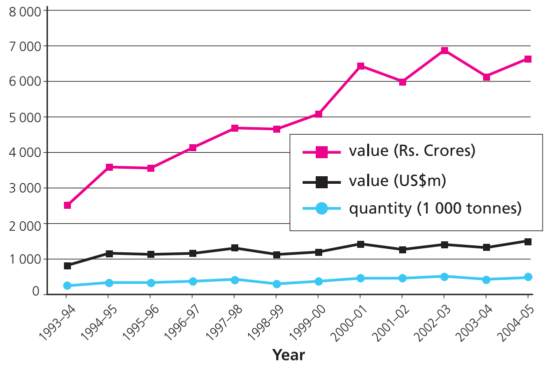
INTRODUCTION

Sea farming has become a promising area of aquaculture all over the world. It is one of the most important and rapidly growing components of Asian aquaculture, contributing substantially to the increased demand for high-value seafood items in the global market. India has a long tradition of aquaculture and is a world leader after the People's Republic of China, contributing about 5.2 percent of the total world production in 2003 (FAO, 2005). A subcontinent with seas on three sides, India has a long coastline of about 8 129 km. The country's continental shelf is estimated as 0.5 million km^2 and its Exclusive Economic Zone (EEZ) encompasses 2.2 million km^2. The southern edge of the Indian Peninsula extends into the Indian Ocean, with the Bay of Bengal on its eastern part and the Arabian Sea on the west. The mainland is surrounded by groups of islands off both the east and west coasts. The Andaman and Nicobar Islands are located in the Bay of Bengal, while the Lakshadweep Islands are scattered in the Arabian Sea. The sea coast along the mainland and around the islands provides a vast scope for the development of sea farming, which has considerable potential to augment seafood production for domestic and export markets.

STATUS OF COASTAL AQUACULTURE

Despite its huge potential, the development of coastal aquaculture in India has been mainly confined to brackishwater shrimp culture and freshwater scampi culture in the maritime states. In fact, the country has a rich tradition of shrimp culture, with various traditional practices followed in different regions to grow shrimp in their natural habitats. Taking a cue from the traditional practices, scientific systems have subsequently been evolved to culture shrimp in protected and manually controlled regimes. Presently over 167 500 ha are used for shrimp farming in the coastal states, with as much as 50 000 ha still being cultivated using traditional practices. Similarly, freshwater prawn farming is also becoming more popular in India, as its practice is not just restricted to the coastal states, but is also making inroads in the inland states. Currently about 42 000 ha are estimated to be under freshwater prawn farming, and with the standardization and stabilization of technology, this sector is poised to expand further.

Figure 1
Export of marine products, 1993–94 to 2004–05



The marine products export from India has been rising over the years, and the current export is worth about US$1 478 million (Figure 1). Frozen shrimp is the largest export item in terms of value, contributing 64 percent of the total export earnings, followed by frozen cephalopods (15 percent), frozen fish (11 percent) and dried fish (2 percent). The European Union (EU) with a share of 26 percent is the largest market for seafood from India, followed by the United States of America (23 percent), Japan (18 percent), the People's Republic of China (10 percent) and Southeast Asia (9 percent). India has the capacity to process 16 250 tonnes of seafood per day, as there are about 425 processing plants with modern facilities engaged in this sector. However, a lack of availability of raw material is one of the major problems faced by the seafood processing plants, as the average capacity utilization is only about 20 percent. In view of this situation, the Government of India is considering the creation of a "seafood hub" in order to handle the importation of raw materials for processing and re-export.

As stated above, shrimp play an important role in the seafood export earnings of the country. It is estimated that nearly 63 percent of the shrimp exported from India is sourced from coastal aquaculture (Figure 2). Hence, coastal aquaculture plays a significant role in marine products exports from the country.

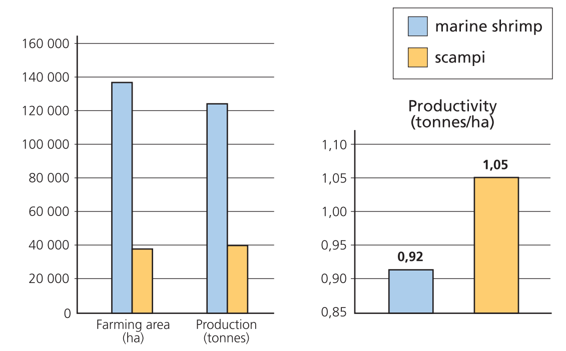
The development of both brackishwater shrimp farming and freshwater prawn farming has been well supported by the process of backward and forward integration with necessary ancillary industries. Presently there are about 350 hatcheries in India with a built-in capacity of 14 billion seed per annum to supply quality seed for both shrimp and scampi culture. Broodstock collectors, nauplii producers, nurseries, water quality analysis laboratories, polymerase chain reaction (PCR) laboratories, etc. are also functioning to support the operations.

Another vital sector for the sustainable development of coastal aquaculture is the feed and feed inputs. Over 30 domestic feed mills are supplying shrimp feed to the farmers, apart from the imported brands. Various forms of other inputs such as probiotics, immunostimulants, Zeolite, benzalkonium chloride (BKC), etc. are also marketed to help produce successful crops. The country's shrimp farms have been periodically affected by white spot disease (WSD), and the farmers are adopting various management measures to prevent crop loss and ensure sustainable production levels.

The Marine Products Export Development Authority (MPEDA) of the Government of India has been playing a major role in promoting coastal shrimp and scampi cultivation in the country, as shrimp constitute the major revenue earner in the export market. The revolution in coastal shrimp culture started when MPEDA established two modern shrimp hatcheries on the east coast, with overseas technological tie-up. Subsequently, scientific commercial shrimp farming practices were also demonstrated to farmers through pilot projects. This sector, which has witnessed a sudden upsurge with large-scale development, faced several challenges from environmentalists, lawmakers, financiers, etc. apart from in-house problems such as the onslaught of diseases. However, the situation has stabilized and is now streamlined with the enactment of the Coastal Aquaculture Authority Act facilitating statutory and regulatory control over coastal aquaculture.

Small and marginal farmers largely run the shrimp culture sector in India. In order to empower these farmers, MPEDA has mooted the concept of forming "aquaculture societies" in various farming villages through a project undertaken by MPEDA in

Figure 2
Farm production of marine shrimp and scampi during 2004–2005



association with the Network of Aquaculture Centres in Asia-Pacific (NACA) on Shrimp Disease Control and Coastal Management in India. Aquaculture societies are expected to improve the socio-economic condition of the small-scale and marginal farmers by assuring them sustainable production levels through adoption of Better Management Practices (BMPs) to reduce the risk of diseases and improve production and productivity.

The country is estimated to have about 1.2 million ha suitable for undertaking brackishwater aquaculture. However, only about 15 percent of the available area has been developed, and thus the scope for further expansion is enormous. In order to regulate the development of coastal aquaculture in an environmentally and sustainable manner, the Coastal Aquaculture Authority (CAA) has been authorized by the Government of India to license aquaculture in the coastal region, and the CAA has already framed the relevant norms and guidelines. This CAA, although national in character, will be working through the state governments for the governance of the coastal aquaculture sector.

AQUACULTURE DIVERSIFICATION PROGRAMMES

Attempts with mariculture in India

The development of coastal aquaculture in India has been concentrated mainly on shrimp or scampi, especially in the coastal areas on the landward side, due to their economic importance and the ready availability of technology and markets. Experimental trials have been attempted for other species of commercial importance. Indian research institutes have already standardized the breeding technologies for many potential species; however, commercialization has not materialized for various reasons. The potential candidates for Indian mariculture are listed in Table 1.

TABLE 1
Potential aquatic species for mariculture in India

Common name	Scientific name
Asian seabass	*Lates calcarifer*
Grouper	*Epinephelus* spp.
Milkfish	*Chanos chanos*
Flathead mullet	*Mugil cephalus*
Silver pomfret	*Pampus argenteus*
Cobia	*Rachycentron canadum*
Tunas	*Thunnus* sp., *Euthunnus* spp.
Mud crab	*Scylla serrata*
Rock lobster	*Panulirus* spp.
Edible oyster	*Crassostrea* spp.
Pearl oyster	*Pinctada fucata, P. margaritifera*
Mussels	*Perna viridis, P. indica*
Clams	*Anadara granosa, Paphia malabarica*
Sea cucumber	*Holothuria scabra*
Seaweeds	*Gracilaria, Gelidiella, Kappaphycus,* etc.

As early as the 1970s pioneering experimental work on the breeding and rearing of various potential aquaculture species was carried out in India by the research institutes of the Indian Council of Agricultural Research (ICAR) such as the Central Marine

Fisheries Research Institute (CMFRI) and others. These pilot-scale attempts have proved that breeding and rearing of several species are possible, and the technology was made available for transferring to entrepreneurs. However, the transfer of technology did not result in large-scale development of mariculture activities due to lack of policy to attract investment. Hence, for nearly three decades coastal aquaculture has remained focused only on shrimp culture.

Private entrepreneurs have initiated some pond culture of finfishes such as Asian seabass and milkfish. Fattening of mud crabs and lobsters was also found to be feasible by local farmers. Further, a major project for cultivation and processing of seaweeds has recently started in the southeast coast by a private company. Although mollusc culture has been practiced primarily at the subsistence level by the local fisherman, attempts have already been made for more organized culture of mussels, oysters and clams in some coastal villages. Such projects generally face serious marketing problems due to the limited production levels. Besides, so far there has been no system in India to classify suitable water for shellfish culture based on water quality and the depuration measures needed to meet international product standards. Hence, more efforts are required in this direction.

MAJOR CONSTRAINTS

Policy for mariculture

Although enriched with vast natural resources and numerous species with mariculture potential, sea-farming has not become well established in the country, perhaps due to the lack of a policy on the use of open water bodies. The coastal areas of the country are densely populated and the major occupations of their residents are related to fishing and ancillary activities. Therefore, demarcation of suitable areas for a relatively new venture such as mariculture may invite multi-user conflicts. To initiate such projects, it is very important to involve the local community and frame suitable policy for aquaculture. Coastal aquaculture in the open waters requires statutory support, and the government has yet to make a major policy decision in this regard. Any major effort to commercialize the technology for mariculture will depend on the policy framework.

Technology

Although a variety of native species are available in Indian waters, standardization of the requisite technology for their breeding and culture has yet to be done on a commercial scale. Therefore, streamlining the technology for commercially important species and identifying the products and markets for such species require special attention. If products are sourced from exotic aquatic animals, then their importation into India will require specific permission from a committee set up by the Government of India, *viz.* a “Committee for Introduction of Exotic Aquatics into Indian Waters”. Similarly the technology for these projects will have to be borrowed from abroad through joint venture programmes or bilateral assistance.

Finance

Coastal aquaculture enterprises in India are primarily operated by small and marginal farmers. The corporate bodies that earlier promoted semi-intensive farming with vertically integrated facilities had a slump and have almost withdrawn from this field. As a result, the financing sector is not too ambitious about aquaculture projects. Hence, government support and active participation of financial institutions may be essential to provide an initial thrust to new ventures.

Manpower

The substantial manpower available in the subcontinent is comparatively cheaper, whether skilled or unskilled. However, to train the available human resources to meet the desired standards of knowledge and technical capability will require considerable effort, especially for tuning to the demands of a new sector. Managing open-sea cage culture farms is one such area in which expertise is not readily available in India.

Environmental impacts

Mariculture farms using offshore waters can be divided into land-based flow-through systems, land-based recirculation systems and offshore cage farms. The pollution load from each of these systems will depend upon the type of technology adopted and the intensity of operation. Moreover, some marine regions off the coast of the mainland and around the islands are protected due to their ecological sensitivity. Therefore, when planning any major endeavour in sea-based aquaculture, the potential environmental impacts should be studied to ensure both long-term ecological and economic sustainability.

Marketing issues

Apart from shrimp and scampi culture, the isolated attempts at coastal aquaculture faced serious problems with regard to marketing their produce. While domestic marketing could be explored for value-added products from mariculture, the major projects must be planned using a market-driven strategy with an eye on the emerging markets and products. Fast-moving products in the international markets need to be identified when deciding upon the species suitable for mariculture so that such efforts are economically feasible.

Sea ranching and marine husbandry

Apart from directly contributing to exports, sea farming programmes can also assist in the replenishment of natural resources by adopting suitable sea ranching and marine husbandry operations such as are practiced by some other countries to augment the sea catches. Such programmes, however, require cooperation from hatchery operators to supply disease-free seed and from fishers to protect the stocked animals until they reach a substantial size in natural waters before harvesting.

DIVERSIFICATION OF COASTAL AQUACULTURE – MPEDA'S INITIATIVES

Shrimp remains the single largest and maximum value earner among the seafood exported from the country. It is estimated that cultured shrimp constitute 63 percent of the total quantity of shrimp exported from India. Therefore, in order to diversify the export basket, MPEDA has set out an action-oriented plan for the next five years. The plan envisages increasing the share of non-traditional cultured varieties to about 50 percent of the total production from aquaculture. In order to concentrate on the diversification of coastal aquaculture, MPEDA has therefore, constituted a separate society *viz.*, the Rajiv Gandhi Centre for Aquaculture (RGCA). RGCA has embarked upon various activities to standardize and popularize the culture of potential species that have commercial significance in Indian waters . The following are some of the activities recently taken up by the RGCA:

- breeding of Asian seabass:
- cage culture of Asian seabass;
- fattening of rock lobsters;
- breeding and culture of mud crabs;
- *Artemia* production;
- breeding and culture of groupers; and
- culture of tilapia.

MPEDA has been in regular contact with international organizations to bring in economically feasible technologies for adoption by Indian entrepreneurs. We have also taken up a few demonstration projects in farmers' ponds to encourage farmers to take up the culture of species such as seabass, mullets, milkfish, mud crabs, mussels, oysters, clams, etc.

With a view to developing mariculture in the country, a detailed feasibility study was undertaken during the 1990s through an overseas agency to micro-survey the Indian coast for its potential for offshore farming. The survey revealed that there is great potential for offshore farming along the continental coast of south India and the island coasts. The meteorological and hydrographical data have shown that the maximum wave and current actions are compatible with the best offshore fish-farming equipment. Wave conditions in the Arabian Sea seemed to be a little tougher than in the Bay of Bengal.

The water quality along the coast was found to be stable and good except on the west coast during the southwest monsoon when upwelling is a common phenomenon, creating oxygen depletion zones followed by algal blooms that can adversely affect farming operations. The availability of suitable sea and land areas, service, transport facilities, etc., was found to be adequate except in remote island locations.

On the basis of this survey, it was concluded that about 2 000 km^2 of sea area is ideally available to take up offshore farming with the potential to produce some 8 million tonnes of high-quality marine fish through cage culture practices.

CONCLUSIONS

According to a vision formulated by MPEDA, the seafood export from India is targeted to reach US$4 billion by 2009/2010. To make this vision a reality, the contribution of the aquaculture sector is expected to rise from the current level of US$0.7 billion to about US$1.5–2.0 billion. There is a growing demand for marine finfish, and offshore fish farming can offer new vistas for Indian aquaculture to achieve the set target, advance national economic development and ensure the livelihoods of many more people. This, of course, calls for a positive strategy to formulate policies conducive for mariculture development. Sustainable development and the progress of marine farming will require substantial building of skills in health management and the diversification of markets, in addition to a smooth flow of finance. Concerted efforts from all sides may lead to such developments in the imminent future.

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SEAFDEC support to aquaculture programmes in southeast Asian countries

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BACKGROUND AND RATIONAL

The Southeast Asian Fisheries Development Center (SEAFDEC) is an autonomous intergovernmental body established as a regional treaty organization in 1967 to promote sustainable fisheries development in Southeast Asia. SEAFDEC has a Secretariat as its administrative arm, and four technical departments including the Training Department (TD), which is in Thailand; the Marine Fisheries Research Department (MFRD) in Singapore; the Aquaculture Department (AQD) in the Philippines and the Marine Fisheries Resource Development and Management Department (MFRDMD) in Malaysia.

SEAFDEC focuses on developing fisheries potential through training, research and information services to secure the food supply by rational utilization and sustainable development of the fisheries resources within the region. Its Member countries are Brunei Darussalam, Cambodia, Indonesia, Japan, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

The Aquaculture Department (AQD) was established to develop aquaculture potentials of the region with four research stations covering marine, brackishwater and freshwater areas. AQD has carried out research, technology verification, training and information programmes on several aquaculture aspects, e.g. managing broodstock and improving seed quality, developing responsible aquaculture techniques and stock enhancement.

In 2001 ministers and senior officials responsible for fisheries in the Association of Southeast Asian Nations (ASEAN)-SEAFDEC Member Countries adopted the "Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region (RES & POA)", at the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium: "Fish for the People". The RES & POA are recognized as the common regional policy framework and guidelines for promoting and ensuring sustainable fisheries in the region. The Resolution in relation to aquaculture is cited as follows:

"Increase aquaculture production in a sustainable and environment-friendly manner by ensuring a stable supply of quality seeds and feeds, effectively controlling disease, promoting good farm management and transferring appropriate technology." (No. 12); and

"Promote aquaculture for rural development, which is compatible with the rational use of land and water resources, to increase fish supplies and improve the livelihoods of rural people." (No. 13)

STATUS OF AQUACULTURE PRODUCTION IN SOUTHEAST ASIA

Marine and coastal aquaculture production

In 2003 the world marine/coastal aquaculture production was 59 354 268 tonnes, while the Asia-Pacific region produced 27 222 394 tonnes or 45.86 percent of world production. The Southeast Asian region produced 3 227 634 tonnes or 5.44 percent of global output (Table 1 and Figure 1).

TABLE 1
Marine and coastal aquaculture production, 2003

Area	Production (tonnes)	Percent
World	59 354 268	-
Other regions	32 131 874	54.14%
Asia-Pacific	27 222 394	45.86%
Southeast Asia	3 227 634	5.44%

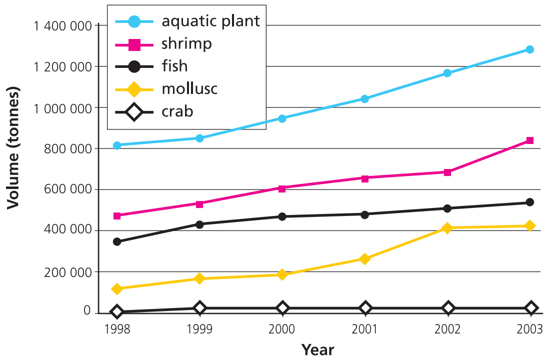
Marine/coastal aquaculture production in Asia-Pacific

For the Asia-Pacific region, the People's Republic of China (including Taiwan Province of China and China, Hong Kong Special Administrative Region) contributed the most production. In 2003 China ranked first with 21 052 292 tonnes or 77.33 percent of the total regional production. This was followed by the Southeast Asian countries with 3 227 634 tonnes or 11.86 percent, while other Asian countries (Japan, Mongolia, the Islamic Republic of Iran, Republic of Korea etc.) were third with a production of 2 655 083 tonnes or 9.75 percent. South Asia (India, Bangladesh, Nepal, Sri Lanka and Maldives) shared 0.65 percent, followed by Oceania with 0.41 percent (Table 2).

TABLE 2
Marine and coastal aquaculture production in Asia-Pacific, 2003

Subregion	Production (tonnes)	Percent
China	21 052 292	77.33%
Southeast Asia	3 227 634	11.86%
Other Asia	2 655 083	9.75%
South Asia	175 796	0.65%
Oceania	111 589	0.41%

Figure 1
Mariculture output by species in southeast Asia, 1998–2003



Cultured marine species in Southeast Asia

During 1998–2003, aquatic plants ranked first in quantity, and their share of production has been growing continuously since 1998 to 56.83 percent. The second group is shrimp – from 1998 to 2003, shrimp production increased by 76.69 percent. Marine fish farming placed third with an increase of 52 percent from 1998 to 2003. The lowest production is crab, but the six-year trend showed a 76.69 percent increase (Table 3 and Figure 1).

TABLE 3
Production of marine aquaculture species in Southeast Asia, 1998–2003

Species	1998	1999	2000	2001	2002	2003	% Increase
Aquatic plant	814 546	855 179	943 391	1 040 631	1 165 458	1 277 460	56.83
Shrimp	473 252	528 039	600 704	654 352	675 009	836 183	76.69
Crab	7 259	13 828	14 088	10 294	15 479	13 945	92.11
Mollusc	117 281	170 117	188 101	261 633	410 740	432 295	90.16
Fish	348 232	427 706	464 275	477 428	505 473	529 285	51.99
Total	1 760 570	1 994 869	2 210 559	2 444 338	2 772 159	3 089 168	-

SEAFDEC SUPPORT TO AQUACULTURE PROGRAMMES IN SOUTHEAST ASIA

Plan of action for aquaculture activities

The Plan of Action, which includes a component on aquaculture and is used as a guideline to develop programmes, projects and activities for the implementation of the Resolution, is as follows:

- Ensure that national policies and regulatory frameworks on aquaculture development are directed towards sustainability and avoidance of conflicts by incorporating consultations with stakeholder groups, implementing aquaculture zoning, considering social and environmental impact and regulating rights of access to, and use of, open water sites for mariculture.
- Ensure production of high-quality seed on a consistent and sustainable basis by providing government support for public and private hatchery development and research, developing domesticated broodstocks and fish reproductive technologies and promoting responsible collection and use of wild broodstock and seed.
- Promote good farm management practices that reduce effluent pollution load and comply with relevant effluent standards through appropriate treatment.
- Reduce the risks of negative environmental impacts, loss of biodiversity and disease transfer by regulating the introduction and transfer of aquatic organisms in accordance with the Regional Guidelines on the Responsible Movement of Live Aquatic Animals and Plants.
- Improve the efficient use of aquatic feeds by regulating the quality of manufactured feed and feed ingredients, providing guidelines on farm-level food conversion ratios and levels of aquaculture effluents and supporting research into developing suitable alternative protein sources to reduce dependence on fish meal and other fish-based products.
- Improve capabilities in the diagnosis and control of fish diseases within the region by developing technology and techniques for disease identification, reliable field-side diagnostics and harmonized diagnostic procedures, and establishing regional and inter-regional referral systems, including designation of reference laboratories and timely access to disease control experts within the region.
- Formulate guidelines for the use of chemicals in aquaculture, establish quality standards and take measures to reduce or eliminate the use of harmful chemicals.
- Build human resource capabilities for environmentally friendly, healthy, wholesome and sustainable aquaculture through closer public and private sector collaboration in research and development, paying particular attention to the emerging need for skills in biotechnology and effectively implementing aquaculture education and extension services.
- Promote aquaculture as an integrated rural development activity within multiple-use of land and water resources available through inter-agency coordination in policy formulation, project planning and implementation, stakeholder consultation, extension services and technology transfer.

Implementation of the SEAFDEC programme

In line with the Resolution and Plan of Action, SEAFDEC launched various regional programmes to support Member Countries. The programmes and their activities in relation to marine and coastal aquaculture are summarized as follows.

Promotion of mangrove-friendly aquaculture: Mangrove-friendly shrimp culture project (2000–2005)

Shrimp culture has been identified as one of major causes of destruction of mangrove forest, and effluents from intensive shrimp culture resulted in negative impacts on mangrove ecosystems. Thus, the programme was initiated with the aim of developing sustainable culture technology packages for shrimp farming that are friendly to mangroves and the environment, and to disseminate such packages to the region through actual demonstration and training.

As part of the programme, verification and refinement of intensive shrimp culture techniques were conducted in Thailand and the Philippines, whereas similar activities for semi-intensive culture were run in Viet Nam and Myanmar. In Thailand, the physical and biological technology for water recycling was studied, which indicated that an integration of bivalves, trickling filter land seaweeds was useful for effluent treatment. The reason is that bivalves could improve the effluent water by removing suspended matter, while seaweeds have the ability to absorb dissolved nutrients. These series of studies also demonstrated the seawater irrigation facility to ensure the proper release of water from shrimp ponds to the sea, as well as plantation for enhancing the food web in water recycling shrimp farms. It served as the basis for the estimation of suitable density of mangrove trees and suitable species of weeds to prevent erosion of pond dikes.

The environmentally friendly schemes verified in the Philippine sites are capable of achieving high productivity and return on investment. The activity in Viet Nam aimed to develop a model for semi-intensive culture and demonstrate a system that can effectively increase production. In Myanmar, the project aimed to promote the most appropriate culture system that could avoid occurrence of viruses and disease in shrimp.

SEAFDEC also conducted research on the nutrient dynamics, environmental impacts and waste inputs resulting from an integrated, closed recirculating, intensive farming system. Under the theme of nutrient research, the study assessed the capacity of mangrove forests to process aquaculture pond effluents. The results confirmed the efficacy of fish as a bio-manipulator in a green-water system to control potentially pathogenic luminous bacteria in shrimp culture.

Training under the scope of the mangrove-friendly shrimp aquaculture project was conducted at both the regional and national levels. On-site training was conducted in Viet Nam, Myanmar and Cambodia. The outcomes from meetings and consultations were also published, and manuals and publications on project achievements disseminated to the public.

Development of fish disease surveillance system (2005–2008)

Antibiotics and other chemicals are often used to control fish disease; however, some of these substances are harmful to human health or can give rise to resistant pathogens in cultured organisms. Therefore, the aquaculture products must be safe for human consumption and a monitoring system for the presence of chemical residues in such products needs to be developed. The programme was developed to enhance disease diagnosis and health management of cultured animals, promote the healthy and wholesome trading of aquaculture products and develop a fish disease surveillance network in the region.

SEAFDEC succeeded in conducting the research to establish and standardize diagnostic techniques for a) detection of white spot syndrome virus (WSSV) in tiger shrimp using polymerase chain reaction (PCR), b) detection of viral nervous necrosis (VNN) in marine fish using cell lines; and c) detection of two serious pathogens of tiger shrimp – *monodon* baculovirus (MBV) and hepatopancreatic parvovirus (HPV). The biology of disease agents and their pathogenesis were also studied to screen economically important fish for the presence of parasites, determine diagnostic methods and study the pathology of infection. Some parasites were detected and identified from grouper, snapper, milkfish and rabbitfish.

The results of studies on the diagnostic methods and parasites contributed to establishment of disease prevention and control methods. Research studies on luminous vibriosis, a major bacterial disease of tiger shrimp, were conducted to develop husbandry techniques such as the use of live bacteria (probiotics) and a green-water culture system as alternatives to chemotherapy in the control of vibriosis. SEAFDEC also established evaluation methods for chemical residues in aquaculture products. The activity addressed the development and standardization of detection methods for chemical residues, especially pesticides and antibiotics, in aquaculture products. The use of antibiotics in shrimp culture was also monitored.

Hands-on training on important viral diseases of shrimp and marine fish was conducted in collaboration with the World Organization for Animal Health (Office international des épizooties, OIE). Various meetings and symposia were organized under the programme to share the most current experience and knowledge on fish disease issues.

As the next-step on fish disease work by SEAFDEC, a programme on "Development of Fish Disease Surveillance System" was developed based on the experiences of the former programme. Its objective is to develop a surveillance system for diseases of aquatic animals in Southeast Asia. Highlighted activities are as follows:

- research and development on the refinement of diagnostic methods and development of new prevention methods for aquatic animal disease;
- surveillance for important viral diseases of fish and shrimp and "mobile clinic" to identify causative agents of serious or unknown infectious diseases; and
- e-learning and hands-on training.

In 2005, surveys and collection of white shrimp samples were conducted to monitor shrimp viruses in Indonesia and the Philippines. The first sampling of rock oyster was taken in Thailand to investigate the presence of OIE-listed parasitic diseases and macro-parasites. Disease diagnosis activities on tiger shrimp were also implemented in Myanmar, Cambodia and Viet Nam. The samples from Myanmar were positive for MBV and HPV but negative for other tested pathogens.

Regionalization of the CCRF: aquaculture development

After the adoption of the Code of Conduct for Responsible Fisheries (CCRF) in 1995, the need to regionalize the Code was examined to clarify and elaborate the generic articles of the CCRF by establishing a set of guidelines taking into consideration regional specificities, including fishery structure; ecosystems; cultural, social and economic factors and other issues of importance in Southeast Asia. Further, the regionalization process was also intended to facilitate the implementation of the CCRF at the national level, where it matters most.

SEAFDEC successfully implemented a programme for formulation and dissemination of a "Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Aquaculture". These regional guidelines were based on Article 9 of the CCRF, which aims to forestall or mitigate the negative effects of aquaculture, from both human and ecosystem perspectives. The regional necessity to promote the implementation of responsible aquaculture was accommodated in the guidelines. Due to the fact that aquaculture farms in the region are generally small, the guidelines also provided specific guidance for efficient use of inputs (fry, broodstock, feed, etc.) to improve production and facilitate responsible practices. In particular, the guidelines elaborated the following principles within the CCRF:

- responsible development of aquaculture, including culture-based fisheries, in areas under national jurisdiction;
- responsible development of aquaculture, including culture-based fisheries, within transboundary aquatic ecosystems;
- use of aquatic genetic resources for purposes of aquaculture, including culture-based fisheries; and
- responsible aquaculture at the production level.

Integrated Regional Aquaculture Program (IRAP): Aquaculture for rural development and supply of good quality seeds (2000–2005)

In response to the need for promotion of sustainable aquaculture in the region, this programme was initiated to assure a supply of quality seed stocks of various aquatic commodities and that aquaculture development will benefit the rural populace through consultations, demonstration and dissemination of specific aquaculture technologies.

The programme on "Aquaculture for Rural Development" is expected to come up with appropriate responsible aquaculture technologies that will help alleviate poverty and ensure food security for people in the rural areas. The other programme, called "Supply of Good Quality Seeds", focuses on appropriate responsible seed production technologies in support of aquaculture and stock enhancement in the region. These two components of IRAP were implemented together and linked with each other. The activities under IRAP covered pilot demonstration, research, training and information dissemination. The benefiting countries expressed their interests in specific aquatic species. Although most priority activities identified by ASEAN countries involved freshwater systems, marine species were selected as the interest of Malaysia, Myanmar, Thailand and Viet Nam.

Grouper, seabass and mud crab were species selected to be included in both activities in Myanmar, which were aimed at utilizing the coastal and marine resources for aquaculture in order to alleviate the social economy of the rural communities. Viet Nam considered milkfish and siganids as priorities for both activities, aiming at promoting the adoption of their culture technologies in coastal areas. Malaysia focused on the production of disease-free grouper, with the aim of producing such grouper seeds by improving broodstock management. Thailand was interested in cage culture of abalone and Babylonia snail, including studies on their growth, survival rates and food conversion ratios (FCRs) to assess the possibility of extending the techniques to fishers in coastal areas.

Broodstock management and seed quality improvement of cultured species; and development of responsible and sustainable aquaculture techniques

The programme on "Broodstock Management and Seed Quality Improvement of Cultured Species" addresses problem areas related to broodstock management, genetic improvement and improvement of hatchery production technologies for major cultured species. The other programme, "Development of Responsible and Sustainable Aquaculture Techniques", aims to develop sustainable aquaculture technologies having minimal impact on the ecosystems by promoting efficient aquaculture systems and designs for maximum sustainable productivity. The studies focused on abalone, mud crab, shrimp and marine fish.

Integrated abalone production

This consists of four components:

- seed production to study the enhancement of natural flora conducive for settlement and microbial communities;

- intermediate culture to assess the economic viability of land-based nursery in tanks as well as the technical and economic viability of open-water nursery in cages;
- grow-out culture in bottom-set and suspended cages; and
- stock enhancement to evaluate the results of SEAFDEC stock enhancement trials conducted earlier.

Mud crab seed production

This programme has the following objectives:

- to refine broodstock management and hatchery-nursery techniques;
- to develop production of mud crab juveniles from hatchery-produced megalopae as a new industry;
- to determine populations and fisheries to quantify growth, migration and mortality rates of *Scylla* species; and
- to develop mangrove pond aqua-silviculture production systems and trials of stock enhancement through release of hatchery-reared juveniles into mangrove habitats.

Shrimp domestication

The programme aims to produce broodstock of native shrimp species – *Penaeus monodon*, P. *indicus*, and *P. merguiensis* – genetically selected for desired heritable traits. Specifically, it is expected to come up with:

- technology development to produce viable *P. monodon*, *P. indicus* and *P. merguiensis* broodstock in captivity and determine its economic viability;
- evaluation of the commercial viability of *P. indicus* and *P. merguiensis* hatcheries and;
- technology development for production of known live feed for shrimp broodstock such as the brine shrimp and marine polychaetes.

Marine fish seed production

This aims to:

- develop, refine and package marine fish seed production technologies;
- test the economic feasibility of marine fish seed production;
- develop and improve broodstock diets of marine fish; and
- develop test kits for egg/larval quality and VNN diagnostics.

The activities in relation to marine and coastal aquaculture include:

- pathogenesis and control of subclinical infection of VNN in broodstock of grouper;
- insulin-like growth factor II as molecular markers for egg quality in finfish and mud crab; and
- reproductive and larval performance of rabbitfish.

Research and development of stock enhancement for species of international concern: stock enhancement for threatened species of international concern (2005–2009)

Heightened public interest in environmental protection and resource conservation has become an important factor in fisheries development. To address these environmental concerns, particularly those related to threatened or endangered species, SEAFDEC has undertaken a programme whose aim is to develop ecologically sound strategies for stock enhancement, including hatchery production and release of genetically diverse and disease-free juveniles. It is also expected that stock enhancement technologies and social strategies will be transferred to the countries in the region.

The programme initially focuses on depleted species for which hatchery technologies have already been developed. The activities include:

- a regional workshop to review the status of stock enhancement in Southeast Asia, identify threatened species and assess the existing technologies for such species;
- research on strategies for sea ranching and stock enhancement;

- verification of developed and established technologies; and
- training and information dissemination on stock enhancement.

In 2005 a consultation was organized and the two selected species were abalone and seahorse. As part of research and development, seed production of abalone and its marketing have been conducted in AQD. The assessment of potential sites for stock enhancement for abalone and seahorse has been implemented.

Collaboration with other organizations

Research institutes and universities in the Philippines

A collaborative programme on "Aquaculture Biotechnology" is being implemented under cooperation with the National Fisheries Research and Development Institute (NFRDI), Mindanao State University (MSU), the University of the Philippines in the Visayas (UPV) and the University of Eastern Philippines (UEP). The programme, which is implemented through training courses to transfer knowledge and skills in aquaculture biotechnology, aims to develop:

- methods for enhancing growth and reproduction in commercially important aquaculture species;
- superior stocks for aquaculture; and
- rapid diagnostic techniques for fish diseases.

Private sector and concerned government agencies in Philippines

With collaboration from the above agencies, a programme on "Technology Verification and Dissemination" was developed aiming at fast tracking the commercialization of environmentally friendly aquaculture technologies for economically important cultured species, i.e. shrimp, crabs and groupers. This is done through demonstration and hands-on training on technical and economic viability and sustainability of the technologies in the Philippines and also in other Member Countries. The programme intensifies technology transfer activities for sustainable aquaculture to improve fish production and generate employment, livelihood and export revenues.

WorldFish Center and Bureau of Fisheries and Aquatic Resource of the Philippines

The programme on "Dissemination and Adoption of Milkfish Aquaculture Technology in the Philippines" has been implemented to analyse the production, market and policy structures of the milkfish industry in the Philippines. It will identify the constraints and opportunities for future growth of the industry, with emphasis on the adoption and impact of technological development. Case studies in hatchery and grow-out production systems were conducted and documented for transfer or replication in other parts of the Philippines.

ASEAN (ASEAN Foundation through ASEAN-Japan Solidarity Fund)

The collaborative programme with ASEAN presently focuses on human resource development (HRD). The programme on HRD for Sustainable Development of Fisheries in Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) Region has been implemented as of March 2005. SEAFDEC launched this project, which includes the area of HRD in aquaculture. A series of *in-situ* participatory workshops will be conducted in various localities of the BIMP-EAGA region. Target participants are front-line fisheries and agriculture officers assigned to promote and assist in aquaculture development at the local level. In December 2005 SEAFDEC successfully implemented the Participatory Workshop for Responsible Aquaculture for Fisheries Officers from Sabah, Malaysia. The topics covered included responsible aquaculture development, mangrove-friendly shrimp culture, marine fish culture in cages, mangrove crab culture, seaweed culture and mollusc culture.

Another programme on HRD on Poverty Alleviation and Food Security by Fisheries Intervention in the ASEAN Region is planned for implementation in the year 2006. The objective of this project is to enhance human capacity of both relevant government fisheries agencies and selected rural fishery communities so as to alleviate the identified poverty status through fisheries intervention covering the areas of rural aquaculture A special focus will also be given to the areas for the rural poor and communities affected by the tsunami disaster in the ASEAN region. The envisaged activities will be to further identify the specific requirements for HRD at each respective site. Various simple technologies to develop rural small-scale aquaculture will be provided to the participants.

Future operations

To support Member Countries, SEAFDEC will effectively continue the implementation of its programmes in line with regional priority issues and needs, particularly for rural development and sustainable aquaculture development that contributes to poverty alleviation. The programmes will include research and development (R&D) and the transfer of knowledge and technology, as well as training and dissemination of information. The future programmes will address the following regional priorities:

- development of a fish disease surveillance system;
- promotion of sustainable aquaculture for rural communities;
- R&D of stock enhancement for species of international concern;
- broodstock management and seed quality improvement for cultured species;
- development of responsible and sustainable aquaculture techniques; and
- research and analysis of chemical residuals and contamination in fish, fish products and the environment, such as fishing grounds and aquaculture fields.

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Perspective from the World Wildlife Fund

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BACKGROUND

Since the early 1980s, aquaculture production in near and off-shore locations has increased rapidly. This increase is a result of the rising demand for cultured seafood and the advent of appropriate structures that can withstand intense weather events that would otherwise destroy the infrastructure.

The rise in mariculture production has brought with it many concerns, both real and perceived. Some of these concerns include:

- blocked access to fishing grounds;
- nutrient loading in near-shore systems;
- wild fish incorporation into aquafeeds;
- lack of reporting on wild fish capture for fattening in cages;
- impingement of sea mammals on longlines and other mooring devices;
- unaesthetic views of seascapes;
- release of chemicals such as therapeutants into natural and public waters;
- transmission of diseases from cultured to wild fish;
- exotic introductions;
- escapes;
- benthic disruption; and
- habitat change and degradation.

Not all impacts will occur at every mariculture site, and further these impacts may be specific to particular species. Nevertheless, the key concerns of those stakeholders that raise these issues and can be affected by the culture activity should be addressed.

The World Wildlife Fund (WWF) has been working on aquaculture-related issues for approximately ten years – identifying the threats that aquaculture can pose and finding viable alternatives to lessen these impacts. In 2002 WWF initiated the Salmon Aquaculture Dialogue to identify the real vs perceived impacts of salmon farming. The approach of the Salmon Aquaculture Dialogue is largely based on the consensus-building process of the Consortium on Shrimp Farming and the Environment (WWF/World Bank [WB]/Network of Aquaculture Centres in Asia-Pacific [NACA]/Food and Agriculture Organization of the United Nations (FAO)/United Nations Environment Programme [UNEP]), which collectively raised awareness and brought a wider and stronger understanding of the impacts of shrimp farming and ways in which those impacts could be mitigated or eliminated. The key to the Consortium's work, along with the various WWF-initiated dialogues, is to build consensus around the body of scientific knowledge present to understand the effects of these aquaculture activities. The largest area of conflict between environmental nongovernmental organizations (NGOs) and producers has been disagreement with or distrust of the science put forth by both sides.

In the Salmon Aquaculture Dialogue and the later Mollusc Aquaculture Dialogue, a wide range of stakeholders including NGOs, producers, buyers, retailers, government officials, community representatives, investors and other influentials are first brought together to identify the key concerns that account for the bulk (75–90 percent) of all of the impacts of culturing a specific species or species group. There are numerous concerns that stakeholders typically raise, but the effort of the dialogue is to focus on the key impacts rather than getting bogged down in developing a comprehensive list of all of the impacts a particular production system might cause. Subsequently, the dialogues seek to expand on the impacts to develop measures to quantitatively reduce these impacts to acceptable levels.

These consensus-building discussions have been widely heralded as a means to identify the true impacts and build collective support on what are the key ways to reduce the impacts of aquaculture. The lessons learned from the dialogues were shared with meeting participants in hopes of promoting a participatory approach to identifying and reducing the negative effects of aquaculture, and in the context of this meeting, more specifically, mariculture. It should be noted that the reason WWF became involved in aquaculture is the acceptance that this form of aquatic animal production must be present to relieve the heightened pressures on wild fisheries stocks.

CONCLUSIONS AND SUGGESTIONS

The workshop was incredibly informative to those who were not familiar with mariculture in the People's Republic of China, and bringing these issues into a regional perspective is critical for the success of producers and the sustainability of the environment. The organizers provided a myriad of regional perspectives on the mariculture of molluscs, fish and seaweeds in the region. From this, it became apparent that the sharing of this information would prove vital to the continued productivity and enhancement of the coastal environment. There are several concerns that, from an environmental NGO perspective, need to be addressed.

- Education – Above all else, there is a need for education both at the producer level and the government level. This education appears to be needed at some of the most basic levels where coastal ecosystem organism co-dependence is explained.
- Coastal zone planning – Where are the different regions as far as zoning and management of the coastal zones? Any effort to improve on these systems needs government participation and acceptance.
- Vision – Is there a clear vision of what the process of bringing regional perspectives together is trying to accomplish? Sharing knowledge promotes better management and avoidance of duplicated impacts. But this process and effort could be most beneficial if regional producer associations could be developed and tasked with furthering the information sharing at a more grassroots level.
- Baseline data – To measure any impact, baseline data is necessary. Monitoring of the current coastal ecosystems by no one else except the producers that inhabit them is important and should be encouraged in a standardized manner.

The Southeast Asia SEAPLANT Network: an initiative of IFC-PENSA

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SEAPLANT.NET is an initiative of the International Finance Corporation Program for Eastern Indonesia SME Assistance (IFC-PENSA). The programme is funded by the IFC, the Asian Development Bank (ADB) and the governments of Australia, Canada, Japan, the Netherlands and Switzerland. IFC-PENSA products and services provide technical assistance and capacity building facilities to SMEs in Indonesia and the Philippines where the programme is known as PEP Philippines.

Initial emphasis is on *Kappaphycus* spp. (*K. cottonii*) and *Eucheuma* spp. (*E. spinosum*). These tropical seaplants are grown primarily in the Philippines and Indonesia where total combined production of almost 200 000 tonnes per annum produces farm gate revenues of more than US$150 million per year. These plants are the world's major source of the biopolymer known as carrageenan.

The focus of SEAPLANT.NET is on working with MSME (micro, small and medium enterprises) to make them effective business units. Special emphasis is laid on the aggregations of family farm units that comprise most of the enterprises involved in seaplant production. The tools and solutions provided by SEAPLANT.NET facilitate the availability, access and applicability of the six groups of essentials that are necessary before any enterprise can prosper. These essentials are fair finance; fair access to global markets; communication and logistics; essential goods and social services; strategic alliances; and science and technology.

The SEAPLANT.NET value proposition is that value chains can be sustainable if stakeholders benefit from transparently adding value… not from processes that make value chains opaque. The overall seaplant approach is to link sustainable seaplant sources through near-source "mini-factories" to end users through a system by which crops are transparently "tolled" through process facilities.

With tolling systems, farmers are aggregated into enterprise units that retain crop ownership as value is added and farmer enterprises get paid for value-added products rather than for raw crops. The end-products of SEAPLANT.NET-facilitated seaplant value chains are "ingredient building blocks" such as dried seaplants, solid concentrates and liquid concentrates. These are marketed globally to further processors, value solutions providers and technically advanced end users.

In the long run, SEAPLANT.NET will facilitate sustainable growth in seaplant value chains by expanding the number of crops grown, promoting integrated coastal zone development, developing sustainable, appropriate systems for adding value near seaplant sources, and facilitating the development of more innovative products for wider local and global markets.

Health issues in mariculture in the Asia-Pacific region: an industry perspective

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Asian aquaculture contributes more than 90 percent to total world production. Nevertheless, the industry is paying a price for this achievement in view of the deterioration in environmental and health conditions in fish farming areas. Coupled to this, the intensification of aquaculture in the region has led to disease problems and heavy economic losses. Health problems have two fiscal consequences for the industry: loss of productivity due to animal mortality and morbidity, and loss of trade due to food safety issues. From an industry perspective, we are facing the following health issues:

- Lack of capacity in disease diagnosis and epidemiology. Most Asian farms operate on a small scale and technical support, including disease diagnosis and training, is lacking at the farm level. Asian aquaculture is characterized by an enormous diversity of species, with several dozen marine species being farmed. Consequently, either more resources are needed to understand the basic epidemiology of diseases in the various species or we have to focus our limited resources on fewer species. Once more data are available, better networking and data sharing between scientists in the region will be required.
- Poor health management practices: In Asia, most individual fish farms produce several species of fish. Poor husbandry methods are often practiced, e.g. the use of trash fish as feed. Fry are often sourced from the wild or derived from wild-caught broodstock. These practices are a simple way for pathogens to gain entry to the farm. Furthermore, legislation for and implementation of farm licensing and zoning policies are not in place in most Asian countries. Coupled with a "gold rush" mentality, this often results in too many fish and too many farms in a concentrated area, which in turn facilitates disease transmission.
- Irresponsible movement of live aquatic animals and low awareness of biosecurity: Increased trade of live aquatic animals and the introduction of new species for

farming without proper quarantine and risk analysis in place have resulted in the spread of diseases within and between countries.
- Improper use of antibiotics and chemicals: Irresponsible use of antibiotics and chemicals in aquaculture can lead to residue problems, an increasing consumer concern and the development of drug resistance among bacterial pathogens.
- Unavailability of fish vaccines: In Asia, with the exception of Japan, few vaccines for marine fish are yet available on a commercial scale. The major advantages of vaccination over therapeutic treatments are that vaccines provide long-lasting protection and leave no problematic residues in the product or environment.

The combination of all the above-mentioned factors, together with the diversity of aquatic animals in tropical waters, has led to a truly challenging disease situation in Asian aquaculture. Under the threats of disease epidemics and consumer pressure on food safety, the industry must undergo change and pay more attention to health management. Collectively, this includes the use of healthy fry, quarantine measures, optimized feeding, good husbandry techniques, disease monitoring (surveillance and reporting), sanitation, vaccination, and proper control and biosecurity measures when diseases do occur. Overall, the emphasis must be on prevention rather than treatment.

Integrated mariculture: its role in future aquaculture development

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Looking at the present growth of aquaculture production, it seems feasible that the sector will be able to meet the future challenge and double its production within 30 years. Thus, the interesting question is not if this expansion will take place, but rather how it will be achieved and what the resulting environmental and socio-economic consequences will be. Besides increased inland production from freshwater fish aquaculture, which is traditionally an integral part of agriculture production, a large part of the expansion is also anticipated to take place along the coasts of both developing and developed countries (FAO, 2006). Fish will be the main farmed aquaculture species, but production of more extensive species like bivalves and seaweeds will increase. Coastal areas, especially in developing countries, already experience high pressure from e.g. urbanization and industrialization that has resulted in both terrestrial and marine ecosystem degradation. Potential impacts from any aquaculture development will mainly be determined by culture system characteristics (species, intensity, technology, etc.) and site characteristics (nature of the landscape and seascape, waste assimilating capacity, waste loadings, social structures, etc.). Generally, some aquaculture systems can be identified as being more sustainable as compared to others. However, in each case of aquaculture development, local constraints from environmental and socio-economic perspectives need to be considered. Under some circumstances, more "environmentally friendly" species may fail to meet some important aspects of sustainability.

To meet future protein demand, increased aquaculture production should come from species not dependent upon high-food-grade raw materials, i.e. fishmeal and fish oil produced from fish species suitable for human consumption. This implies a focus on species able to utilize vegetarian diets and on extractive species (filter feeders and seaweeds). Development of alternative protein feed sources will also play a role in production of fish species that today depend on fishmeal-based feeds (see Tacon, Hasan and Subasinghe (2006) for a review on feed development). The rapid-scale increase now seen in human activities in coastal areas puts further pressure on the already impoverished functions of coastal ecosystems. Therefore, legislative guidelines, standards and controls regarding the discharge of nutrient wastes from various sources (including aquaculture operations) are starting to become more stringent in many countries. Development of integrated mariculture, i.e. bioremediation via integrated concepts with a capacity to improve the quality of the discharged water, may facilitate the aquaculture industry to avoid non-compliance and gain both direct and indirect benefits from improving water quality and coastal ecosystem health.

The findings from many recent studies on both land-based and open marine culture systems show the potential for adopting integrated mariculture systems (see reviews in Troell *et al.*, 1999, 2003; Chopin *et al.*, 2001; Neori *et al.*, 2004). The European Aquaculture Society meeting "Beyond Monoculture", held in Trondheim, Norway in 2003, concluded that we now have accumulated enough data to support the biological demonstration of the concept of integrated aquaculture. Further conclusions were that no universal integrated system exists, the choice of technology and species is different for different regions and different socio-economic conditions and that we now need to demonstrate its applicability at commercial scales, including analyses of both biological and economic performance.

Despite some 20 years of research, today only a few commercial integrated mariculture systems exist. Most recent marine integrated systems have been experimental and small scale, which implies difficulties when extrapolating the results (efficiency and economic performance) to commercial scales (Troell *et al.*, 2003). There are, however, integrated systems that are operating at larger scale and being commercial. The best examples can be found in China where suspended multi-species aquaculture operates at scales of whole bays. For example in Sungo Bay, east of the Shandong Peninsula, scallops are cultivated together with kelp, abalone and fish, in cultures extending 8 km offshore. Another integrated open-water culture of kelp with salmon and mussels operates in the Bay of Fundy, Canada. Abalone farming in South Africa and Israel are other examples of integrated mariculture systems performed at larger scales on land. Abalones are cultured in land-based flow-through tank systems and seaweeds are cultured in the wastewaters from the abalones (Troell *et al.*, 2006). In Israel the integration also includes fish (Neori *et al.*, 2004).

The general benefits from integrated practices are additional income from co-cultured crops and reduction of nutrient release to the environment. There are other benefits such as facilitation for recirculation of waters (i.e. through ammonium removal and oxygenation by seaweeds), which also could result in reduced pumping costs and increased water temperature (resulting in higher growth) (Troell *et al.*, 2006). The ability to operate in recirculation mode may be important in cases where intake water may need to be shut off for a limited period (e.g. during red tides or oil spills). The cultivated additional crop, i.e. the extractive organism, can in itself generate an economic value (marketable product) or be used as input to co-cultured species. Seaweeds cultivated with abalones are used as abalone feeds, and their quality has been proven to increase when cultured in abalone wastewater. For species like abalones that in some countries depend to a large extent on wild-harvested kelp, future expansion may depend on increased cultivation of seaweeds when wild kelp resources become exhausted (Troell *et al.*, 2006). Additional arguments for integrated mariculture include possible social benefits and diversified production (risk reduction – i.e. increased portfolio).

The practice of integrated farming also generates additional costs that may impact negatively on overall farm economy. These costs could include additional investments, maintenance and the need for increased and complementary skills. There might also be an increased risk for negative interactions between species (i.e. spread of diseases, parasites, chemicals, etc.). These potential costs and interactions may only be revealed when practicing integration at large scales. Scale is also important, as many beneficial interactions probably are limited by scale (i.e. spread of dissolved nutrients and particulate matter) (Troell and Norberg, 1998; Troell *et al.*, 2003).

The fact that few integrated mariculture systems exist could indicate that the incentives for their practice are weak. It is important to acknowledge that present aquaculture business models do not consider and recognize the economic value of the biomitigation services provided by biofilters, as there is no cost associated with aquaculture discharge/effluent in mariculture systems. Regulatory and financial incentives may therefore be required to clearly recognize the benefits of the extractive components in a culture system (shellfish and seaweed). A better estimate of the overall cost/benefits to nature and society of aquaculture waste and its mitigation would create powerful financial and regulatory incentives to governments and the industry to jointly invest in integrated approaches.

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The future of mariculture: a regional approach for responsible development in the Asia-Pacific region

FAO/NACA Regional Workshop
7–11 March 2006
Guangzhou, China

Aquaculture in the Southeast Asian region has been growing steadily over the last few decades, requiring more space to accommodate it. The search for additional areas to expand the aquaculture industry as a whole and the identification of new farming species of commercial value to satisfy the growing local and export markets are pushing the sector in some countries to broaden activities in the sea, including further offshore where more space is available and where, to a lesser extent, competition is currently not so intense. The Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the Network of Aquaculture Centres in Asia-Pacific (NACA) organized the regional workshop entitled "The Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region" from 7 to 11 March 2006. The workshop was conducted in collaboration with the Ministry of Fisheries of the People's Republic of China and the Guangdong Ocean and Fisheries Administration.

The workshop was convened in response to requests from FAO and NACA member countries to identify key trends and issues affecting mariculture growth in the Asia-Pacific region and to strengthen regional collaboration for future responsible development of mariculture.

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