Food and Agriculture Organization of the United Nations

RAP PUBLICATION 2014/20

Proceedings of the Regional Consultation on Sustainable Intensification of Aquaculture in Asia and the Pacific

Bangkok, Thailand, 9–11 October 2012

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC
Bangkok, 2014

ISBN 978-92-5-108586-8 (print)
E-ISBN 978-92-5-108587-5 (PDF)

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For bibliographic purposes, please reference this publication as:

Miao W., Wilkinson S., Ellis W. (eds.) (2014) Proceedings of the Regional Consultation on Sustainable Intensification of Aquaculture in Asia and the Pacific. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2014/20, 76 pp.

FOREWORD

Fish has now become an important source of diet protein for the world's population. The world's per capita food fish supply reached 19.2 kg in 2012, which provides about 17 percent of the animal protein in people's diet globally.[1] The supply of fish for human consumption has significantly improved from the level of 1990 at 13.5 kg despite the stagnant capture fishery production. The rapid growth of aquaculture production has played a major role in raising the fish consumption level while meeting the increased demand caused by population growth. In 2012, the global cultured food fish production reached 66.6 million tonnes, which supplied about 50 percent of the food fish for the world's population.

Population growth will significantly increase the demand for fish in the world in the coming decades. It has been estimated that by 2030, just to maintain the current per capita level of fish consumption, the world will require at least 23 million tonnes more food fish above the current level. With stagnant capture fish production and the Asian contribution to the world's aquaculture (90 percent), the increased demand for fish will need to be met largely by the growth of aquaculture in Asia.

As the most populous region in the world (4.18 billion in 2011)[2], it is currently forecast that Asia's population will grow by more than 700 million by 2030.[3] Asia is also the region with the most dynamic growth of the economy. This population growth and economic development is expected to result in significant increase in the regional demand for fish in the coming decades. Given the intermediate projection of per capita apparent fish consumption of 25.8 kg for Asia by 2022, regional aquaculture fish production needs to reach 82.45 million tonnes.[4] Assuming stagnant capture fishery production, this implies that Asian aquaculture production needs to increase 40 percent in the next ten years from the production of 58.8 million tonnes in 2012. It also means that the aquaculture production would need to increase by more than 60 percent to meet the projected apparent fish consumption by 2030.

The growth of aquaculture production has been largely attributed to past intensification. The intensification and expansion of aquaculture without proper planning and management has raised increasing concerns about the sustainability of the industry due to its impacts on the environment and natural resources and associated socio-economic issues. It would hardly be possible to meet the increasing demand for fish in the region and the world without aquaculture intensification given the increasing scarcity of water, land and other aquaculture resources resulting from population growth and competition from other uses in the region. Therefore, sustainable intensification will be the key to maintaining the required growth of aquaculture for meeting the increasing demand for fish in the region as well as in the world.

This publication is the output of an FAO-APFIC-NACA Regional Consultation on Sustainable Intensification of Aquaculture in Asia and the Pacific held in Bangkok, Thailand, from 9 to 11 October 2012. The consultation was jointly organized by the Asia-Pacific Fishery Commission and the Network of Aquaculture Centres in Asia-Pacific (NACA). Its aim was to support sustainable intensification of aquaculture in the region. The consultation was attended by 47 participants from 17 country governments, five international and regional organizations, six universities, national think-tanks and the private sector, which enabled an extensive sharing of the available scientific knowledge and country experiences related to sustainable intensification and identification of priority areas for research and development. The publication is expected to provide policy-makers, professionals and various stakeholders an important entry document for promoting sustainable intensification of aquaculture.

Hiroyuki Konuma
FAO Assistant Director-General and
Regional Representative for Asia and the Pacific

[1] FAO (2014) Status of fisheries and aquaculture in the world 2014
[2] http://en.worldstat.info/Asia
[3] OECD – FAO (2013) AGRICULTURAL OUTLOOK 2013-2022
[4] FAO (2014) Status of fisheries and aquaculture in the world 2014

PREPARATION OF THIS DOCUMENT

This publication is the output of an FAO-APFIC-NACA Regional Consultation on Sustainable Intensification of Aquaculture in Asia and the Pacific held in Bangkok, Thailand, from 9 to 11 October 2012. The regional consultation was jointly organized by FAO, the Asia-Pacific Fishery Commission (APFIC) and the Network of Aquaculture Centres in Asia-Pacific (NACA). It was an important regional initiative of FAO to support sustainable intensification of aquaculture for sustainable growth of the sector in the region to meet the future increasing demand for fish in the world and contribute to poverty alleviation.

The regional consultation was attended by 47 participants from 17 country governments from Asia and the Pacific, five international and regional organizations, six universities, national think-tanks and the private sector. The consultation included 12 thematic presentations from renowned scientists and practitioners covering a wide range of subjects related to sustainable aquaculture intensification, 17 country presentations and extensive discussions on key issues and needs for research and technology dissemination in promoting sustainable intensification of aquaculture. The consultation greatly promoted the sharing of up-to-date scientific knowledge related to sustainable intensification and relevant experiences and lessons the countries gained in the process of aquaculture development. The key issues related to aquaculture intensification and the priority needs for research and development that were identified by the consultation participants provide an important entry point for country governments, regional and international organizations, academia and other stakeholders in their effort to support the sustainable intensification of aquaculture in the region.

This proceedings include the executive report of the consultation, extended summaries of thematic and country presentations and other relevant meeting documents. The executive report was drafted by the NACA Information Programme Manager based on the consultation procession and outputs from relevant general and working group discussion. The extended summary of thematic and country presentations were submitted by the presenters or summarized by the NACA Information Programme Manager based on the presentation contents. The responsible officer of the FAO Regional Office for Asia and Pacific revised the executive report of the consultation, and compiled and edited the complete publication. An external consultant helped in the language editing of the extended summaries. The thematic and country presentations are available at NACA's website (www.naca.org).

ACKNOWLEDGEMENTS

The completion of the publication was primarily attributable to all the consultation participants from country governments, regional and international organizations, academic institutions within and outside the region and the private sector, whose active participation and valuable technical inputs ensured the successful outcome and results of the consultation. Special thanks are given to Ambekar Eknath, Director General of NACA at the time and NACA Secretariat staff who supported and contributed to the organization and convening of the regional consultation and preparation of the publication. Special thanks are due to Kesara Aotarayakul for her assistance in the publication of the document.

Simon Funge-Smith, Senior Fishery Officer, FAO Regional Office for Asia and the Pacific, is gratefully acknowledged for his technical advice and contribution to the regional consultation.

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Part I Executive Report

1. Background

The world population has been forecasted to reach more than 9 billion by 2050. To feed these numbers, global agricultural output including crops, livestock and fisheries must increase by around 60 percent from present levels. Our starting position is that globally nearly one billion people are suffering from hunger now. More than half of them, 578 million, live in the Asian region.

Fisheries products play an important role in food security and nutrition by providing low-cost animal protein, healthy fats and nutrients. Fish is often the only affordable source of animal protein available to poor and nutritionally challenged people, and can exceed 80 percent of dietary protein intake in some countries such as Cambodia. Due to stagnant capture fisheries production, aquaculture development is seen as the only sustainable way to meet the increasing world demand. Around 50 percent of global food fish supplies already come from farmed sources.

Asian aquaculture has grown rapidly over the past three decades, and now represents more than 90 percent of global aquaculture output by volume. The growth of the industry has largely been a result of two major factors; intensification through technological advances and increased use of feed and other resources. While the growth of Asian aquaculture has contributed to food security and rural livelihoods, it has also caused significant environmental disturbance.

Intensifying aquaculture production in a *sustainable* manner is a massive challenge. Just to maintain per capita fish consumption at current levels will require an increase in global supply of around 60 percent. The target will be even higher for the Asia-Pacific region, when population trends and dietary preferences are taken into consideration. Meeting this demand using conventional farming practices will not be possible without causing irreversible environmental impact.

The utilization of natural resources in agricultural production is increasingly being understood in terms of the related ecological costs. Maintaining environmental integrity while increasing food production by 60 percent will require that all agricultural sectors reduce their unit production environmental footprint. Many farming practices that are regarded as sustainable today will simply not be sustainable when conducted on a larger scale. Competition for essential resources such as water, suitable farming sites, energy, fishmeal, fish oil and other feed ingredients will inevitably constrain the growth of the industry.

Sustainable intensification of aquaculture means *doing more with less*. Aquaculture must become a more efficient user of natural resources, both in terms of farm productivity and environmental efficiency. Each kilogramme of food grown tomorrow must have less environmental impact than it does today. We need to start building more efficient farming systems now and for tomorrow. As a leading aquaculture region with more than 90 percent of world production, this challenge presents both opportunities and responsibilities for the Asia-Pacific region.

2. Purpose

The main objective of the regional consultation was to *develop a regional strategic policy framework to guide national governments and regional organizations in promoting sustainable intensification of aquaculture in the Asia-Pacific region*. The consultation also sought to identify priority actions for the region and, where possible, practical measures for their implementation.

The consultation specifically focused on intensifying aquaculture through *more efficient use of resources* and environmentally sound practices. Farm productivity and environmental performance must be improved through a combination of forward-looking policies, better management practices and technological improvements, rather than by increasing inputs to the system.

The consultation sought to consider the above issues within the prevailing socio-economic context of aquaculture in the Asia-Pacific region – a sector characterized by large numbers of small-scale, and family-operated farms that require special attention if aquaculture is to continue to contribute significantly towards their welfare. It also sought to identify practical interventions that accounted for this context in order to drive real change.

3. Participation

Participants were selected to share their experiences on the past performance of aquaculture development, to identify issues and constraints to sustainability, and to share success stories and capture promising new directions that would guide Asian aquaculture towards more sustainable practices. The consultation brought together a total of 47 participants (Annex 2), which included:

- Twenty-One national representatives from 17 countries in the Asia-Pacific region
- Fifteen participants from international organizations (World Bank, Intergovernmental Organization for Marketing Information and Technical Advisory Services for Fishery Products in the Asia and Pacific Region (INFOFISH), Southeast Asian Fisheries Development Center (SEAFDEC), the Network of Aquaculture Centres in Asia-Pacific (NACA) and FAO)
- Seven participants from four universities and two policy think-tanks
- Two major corporate aquaculture interests (CP and Cargills)
- One farmer association, the Thai Federation of Shrimp Cooperatives
- One independent expert

4. Procession of the consultation

The regional consultation was successfully convened in Bangkok, Thailand, from 9 to 11 October 2012 through the cooperation of FAO with APFIC and NACA.

4.1. Opening session

The workshop was opened by Mr Hiroyuki Konuma, FAO Assistant Director-General and Regional Representative for Asia and the Pacific with his opening remarks. Mr Ambekar Eknath, Director General of NACA and Mr Chirdsak Vongkamolchoon, Deputy Director-General of the Department of Fisheries, Thailand, gave welcome remarks. Mr Konuma reviewed the development and contribution of aquaculture industry in Asia and the Pacific and emphasized the importance of sustainable intensification of aquaculture in meeting the increasing demand of people for fish which resulted from anticipated population growth and economic development in the coming decades. In his speech, he expected a fruitful consultation that would effect the sharing of the existing knowledge and successful experiences of sustainable intensification of aquaculture in Asia-Pacific and other parts of the world, identify the issues and constraints in sustainable intensification of aquaculture and recommend regional strategies to promote sustainable intensification of aquaculture.

On behalf of Mr Jia Jiansan, Deputy Director, FAO Fishery Resource (FIR) Division, Fisheries and Aquaculture Department, FAO, Rome, Mr Rohana Subasinghe, Chief, Aquaculture Branch, Fisheries and Aquaculture Management Division, made a keynote address on "Aquaculture sustainability: Towards 2030". He presented a global overview on anticipated aquaculture development target by 2030 and

elaborated the importance of aquaculture sustainability in achieving the development target. He highlighted what and how Asia and the Pacific region should contribute to such sustainable development for achieving the global development target of aquaculture sector.

4.2. Thematic presentations by invited resource persons

Fifteen resource persons invited from around the world made presentations, which introduced extensive knowledge, technologies, management practices and situation analysis across all thematic areas related to sustainable intensification of aquaculture. The invited speakers provided their insight on key issues related to sustainable intensification of aquaculture, such as aquaculture inputs, aquaculture health management, aquaculture products trade, interaction between aquaculture and the environment and the related social and economic issues. Their presentations provided very important inputs for the working group discussions.

4.3. Country presentations

Government representatives from eight countries in the region shared their successful experiences in how to promote sustainable development of aquaculture through improved planning, management, enabling policy measures and public services.

4.4. Working group sessions

The consultation conducted three dynamic working group sessions for developing the regional strategy to promote sustainable intensification in Asia and the Pacific. The working group sessions and their outputs were summarized as follows:

Working Group Session I: Priority issues and options for sustainable intensification of aquaculture in Asia-Pacific:

Participants identified key issues, constraints and opportunities in sustainable intensification of aquaculture, focusing on key Asian aquaculture commodities and systems in detail.

Working Group Session II: Development of a regional strategy and action framework to support sustainable intensification of aquaculture in Asia-Pacific:

Participants discussed and drafted a regional strategy and action framework for promoting sustainable intensification of aquaculture in Asia and the Pacific with the inputs from the thematic presentations and outputs of previous working group session.

Working Group Session III: Development of strategy and action framework for promoting sustainable intensification of aquaculture at the national level:

Participants discussed strategies and plans to facilitate sustainable intensification of aquaculture at the national level, drawing on the experience papers and case studies presented by national representatives and outputs of the Working Group Session II.

4.5. Finalization of regional strategy and action framework promoting sustainable intensification of aquaculture in Asia and the Pacific

A Final Plenary Session was convened to discuss, revise and endorse the draft regional strategy and action framework for supporting sustainable intensification of aquaculture in Asia and the Pacific.

5. Recommendations on regional strategy promoting sustainable intensification of aquaculture in Asia and the Pacific

A primary driver of intensification in Asia is the desire of households to improve their livelihoods and increase income. As with all livelihood activities, aquaculture must be profitable enough, relative to other on-farm and off-farm occupations, to sustain the interest of farmers.

The concept of sustainable intensification is derived from agriculture with limited potential for increase in area of terrestrial crops and livestock. However, aquaculture, the third and relatively underdeveloped food producing sector, has a great potential to expand on land and in water in most Asian countries. There is a considerable potential to integrate aqua-farms with or replace crops and livestock as well as to establish aqua-farms in natural and artificial inland and coastal water bodies. Intensification of aquaculture systems thus presents both opportunities as well as challenges.

The Regional Consultation identified key regional challenges to sustainable intensification of aquaculture in the Asia-Pacific region. Addressing these through regional/national actions and with private sector support, will help remove bottlenecks and constraints. The wide range of challenges and required action is a comprehensive picture of how sustainable intensification must be approached across multiple sectors and requires action from both government and private sectors.

Intensified aquaculture requires increasingly robust regulatory framework to limit the potential impacts of overcrowding, environmental pollution, unregulated movements, biosecurity, food safety and the need for quality assurance on inputs. Since the bulk of the world's aquaculture takes place in developing and newly industrialized countries, these frameworks are often insufficiently developed to provide necessary assurance to markets, which has resulted in a rising demand for certification, business-to-business quality assurance schemes.

The constraints to sustainable intensification or the key bottlenecks which if resolved would enable greater efficiency and intensification are highly context specific. As a result, any kind of system will only require a subset of the issues below to be addressed.

In terms of regional initiatives there are a number of key issues that could be identified as priorities.

5.1. Improve the supply of quality seed of genetically improved strains and diversified species

Intensification of aquaculture production can be achieved through improved performance of the cultured species. There are considerable performance gains possible with selective breeding that remain to be captured, since most aquaculture stocks are not highly domesticated or remain essentially wild type. Poor broodstock and genetic management also result in performance loss and these trends will contribute greatly to the improvement of less intensive farming systems. The following actions are recommended:

5.1.1. Promote the regional sharing of aquatic genetic resources

There is a considerable potential for improvement of breeds of cultured species through the selective breeding of different stocks and strains. In some cases, this requires movement between countries and sharing of germplasm. The value of genetic resources is now increasingly recognized and, therefore, access to and sharing of germplasm is increasingly constrained. Many countries have stringent regulations.

- Look to the Nagoya/Cartagena protocols as a means to enable wider access to germplasm and reduce concerns over right to germplasm.
- Establish regional agreements on the sharing and exchange of aquatic genetic resources – Nagoya protocol.
- Strengthen the use of relevant protocols for responsible movements as outlined in the FAO Code of Conduct for Responsible Fisheries and Aquaculture, use of risk assessment and respect for the issue of Convention on biodiversity (CBD) in case of irresponsible movement of broodstock and introductions of species and/or strains.
- Facilitate bilateral arrangements for sharing germplasm.
- Establish a network for sharing information and experience on genetic improvement (Regional, NACA/FAO).
- Establish a regional broodstock development and genetic enhancement programme for some key species.
- Assist resource-limited countries to access quality broodstock for some key species and varieties because they have limited capacity to maintain genetic quality of broodstock (e.g. through inbreeding) due to small national hatchery capacity.
- Develop tropical cold water species programmes for upland regions, where aquaculture development and intensification remain constrained by seed supply.

5.1.2. Capacity development for the improvement of species and varieties, and seed quality

- Develop broodstock genetic improvement and dissemination programmes (national, private sector).
- Improve management and regulation of hatcheries (seed quality, hybridization etc.).
- Build level capacity in broodstock/hathery management (national).
- Provide technical assistance for some countries that need it to build up national breeding programmes.
- Consolidate a resource base to set up and operate breeding programmes (e.g. manuals, capacity building activities).

5.1.3. National domestication and breeding programmes for commodity species

There is a need to encourage public and private collaborative initiatives in domestication and broodstock programmes. *Penaeus vannamei* has benefitted from joint industry stock improvement programmes, followed by well-financed private sector breed development programmes. Superior strain of Tilapia has been developed through a multi-country international breeding programmes. There are some well-developed national programmes in the Asian region for some species (e.g. India, Jayanti rohu, tilapia), with improved germplasm presently being disseminated within country.

- Asia would benefit from the domestication of several other commodity species such as Indian and Chinese major carps. There are also several other high-value species of interest.
- Establishment of well-funded basic breeding programmes for rapid domestication and broodstock management programmes.
- There would be benefit from cooperation between public and private players for key commodities.
- Initial investment for starting a founder population is very high and requires public sector investment.
- There is a strong role for government investment to pre-screen stocks and start the domestication and captive breeding process.

5.1.4. Identification and focus on a limited number of emerging species currently without regional support

Asian consumers have a particular interest in consuming a diversity of fish species which should be encouraged as there is a scope for improvement of a number of breeds. The demand for a diverse range of minor species is unique to Asia with some 166 species currently cultured in significant volumes although a concern is spreading research capacity too widely. These species are often not part of large-scale breeding programmes and are maintained either under state research facilities or within farmers own systems.

- Screen a number of promising species (e.g. climbing perch) for selection and improvement under a regional cooperative breeding programme.
- Take consumer and market requirements into account prior to the establishment of breeding programmes.

5.1.5. Undertake species selection and breeding to fit poor rural areas need for high volumes of small fish

Most breeding programmes for commodity markets target increased size and rapid growth rate. Intensified systems that respond to developing country and poor rural needs should focus on breeding for rapid early growth, high biomass and stress and disease tolerance. This would provide rapid turnover for farmers, could reduce production cost, and the size of fish produced would be affordable to poor consumers. Species of interest for local food security that may not be of immediate commercial interest, typically require national/regional government cooperation to assist in maintaining genetic quality of breeding stocks, as these are not commodities for which the industrial sector has commercial interest.

- Promote adaptive research with small-scale farmers and rural aquaculture systems to innovate on small fish production systems.
- Screen a number of promising species (e.g. climbing perch) for selection and improvement under a regional cooperative breeding programme.

5.2. Strengthen aquaculture biosecurity and health management

Intensified aquaculture depends on high levels of health management. It is more vulnerable to the impacts of disease outbreak due to higher densities and increased levels of investment in operations. The management of health links strongly to the quality of the seed used in the operation. The following actions are recommended:

- Build capacity in the development of farm-level biosecurity plans.
- Build capacity in national/transboundary biosecurity plans (regional, national).
- Build capacity in disease surveillance, contingency planning and response (national).
- Promote specific pathogen free (SPF) programmes for key stocks.
- Promote hatchery certification/quality assurance schemes.

5.3. Improve the availability of high quality and cost-effective aquaculture feed and the utilization of the feeds and feed ingredients

Intensified aquaculture requires more efficient feeds and feed utilization. This also links to the impacts of effluents. Feed costs are the major cost of production and, therefore, sustainable intensification will be highly dependent upon how the feed component of the system can be addressed. The following actions are recommended:

5.3.1. Improve the efficient utilization of feeds and feed ingredients

Efficient and more digestible feeds can reduce adverse environmental impacts leading to higher yield, cleaner/lower water use systems and thereby contributing to moving towards sustainability. Lowering protein level diets would allow more efficient use of feed resources without necessarily compromising performance.

- Address farmer/customer miss-perceptions through communications and education.
- Raise farmer awareness and influence expectations concerning feed protein content (improve awareness regarding the importance of digestible protein versus total protein level in diets) and low fishmeal feeds.
- Assess the current status and future potential of national agriculture to be able to provide plant-based aqua-feed ingredients.
- Provide regional guidance on species/systems feed-protein requirements; opportunities for innovation/mixed feeding schedules; communicate advantages of compounds feed versus fresh fish.
- Use green water through pond fertilization as a strategy to reduce the cost of pellet-fed aquaculture.

5.3.2. Facilitate sourcing of cheaper aquaculture feed ingredients

- Review national regulations to optimize the use of feed towards intensification, especially in relation to protein levels in feed. This could contribute to reducing cost of feed.
- Review aquaculture feed ingredient import policies and tariffs (national).
- Share information on sources and prices of feed ingredients.

5.3.3. Review and reform feed standards

A national standard for feed for each species is a common practice in many countries but appears to be counterproductive (e.g. regulations on total protein level). Total protein level may be unnecessarily high and limits the adaptation of feeds to costs, system and performance increases through genetic improvements. This was largely a historic result of attempting to protect small farmers from poor labelling and sub-standard feeds. There is a need to revisit national policies on mandatory protein inclusion levels in feeds now that there is more competition in feed markets, particularly for intensified systems.

- Improve quality assurance from feed producers, labelling and feed composition through national regulations.
- Revisit national feed regulations and consider recommending liberalization to improve the tailoring of feed to specific systems.
- Strengthen quality/crude content disclosure and monitoring of aquaculture feeds (national, private sector).
- Establish a regional mechanism to bring these types of discussions to the attention of all stakeholders as they have relevance for sustainability.
- Develop a regional advisory note to inform policy and other stakeholders.

5.4. Promote efficient use of land, water and energy

Intensification of aquaculture includes the conversion of other production systems to or integration of other production systems with aquaculture; intensification should not be considered as only increased production per unit area. Thus, sustainable intensification of aquaculture links strongly to agricultural

intensification and diversification of farming systems as well as to the improvement of the livelihoods of small-scale farming households that dominate Asian agriculture as well as aquaculture. Aquaculture will increasingly be challenged for space and water in the region and thus innovations will include utilization of new areas for aquaculture and increased water utilization efficiency. At the same time, consolidation of aquaculture production units is occurring with changing labour and ownership patterns. The following actions are recommended:

5.4.1. Expansion of aquaculture into agricultural land

- Assess the feasibility of the expansion/integration of aquaculture into agricultural land through review of government policies and assessment of relative socio-economic benefits.

5.4.2. Expansion of aquaculture into under-utilized areas

- Assess the feasibility of the expansion of aquaculture area (offshore aquaculture, reservoirs, irrigation infrastructure) with appropriate environmental impact assessment (EIA).
- Regional and international organizations such as FAO, NACA to facilitate aquaculture technology transfer and sharing of expertise based on needs assessment.
- Region advisory on appropriate intensification technologies/strategies.
- Strengthen national capacities for situation appraisal, carrying capacity assessment, EIA, zoning (regional); make the tools for these more accessible.

5.4.3. Ensure aquaculture access to water needed for sustainable intensification

Aquaculture is often treated differently from agriculture with respect to energy tariffs, water allocation, water charges and subsidies in some of the countries in the region.

- Conduct water audits for existing systems and projections for future intensification using life-cycle analysis.
- Government support for infrastructure development for market accessibility and use of energy and water.
- Irrigation systems are typically never intended for aquaculture but future development should consider integration and allocation for aquaculture.
- Promote culture-based fisheries/multipurpose use of water resources.
- Address unresolved issues relating to aquaculture payment for water services, allocation of water for aquaculture and effluent discharges.

5.5. Reduction of environmental impacts of intensified aquaculture

Intensified aquaculture typically requires increased levels of feeding. This raises the challenge of management of effluents and impacts on receiving waters. Reduction, recycling or treatment of wastes and effluents from aquaculture facilities becomes an increasing priority. This also links to both farm biosecurity and feed use efficiency. The following actions are recommended:

5.5.1. Improve management of aquaculture effluent discharge (links to strengthened regulatory framework)

- Develop/strengthen laws and regulations (national level).
- Facilitate the development, dissemination and implementation of better management practices (BMP)/good aquaculture practices (GAP) for communication to farmers (national, regional).
- Strengthen capacity in monitoring and compliance (national).

- Promote appropriate effluent-reduction technologies such as BMPs/GAPs and recirculating systems (national).
- Continuously develop and improve technologies for effluent/waste management, including multi-trophic aquaculture systems (IMTA).
- Encourage a multi-sector approach to waste/by-product use from production and processing.

5.6. Promote culture-based fisheries as an option to intensify production of open waters

The open waters of Asia offer a considerable potential to increase production of fish from food through responsible enhancement. The promotion of culture-based fisheries (CBF) is likely to deliver more immediate yield increases than the investment in technology of intensive approaches such as feed and breed improvement. This is a complex issue since it relates to access to water bodies, social equity arrangements, and competition of water use as well as biodiversity dimensions. The following actions are recommended:

5.6.1. Strengthen research and development for promoting culture-based fisheries

- Explore the socio-economic issues related to increasing CBF opportunities of open waters.
- Ensure that enabling policies are available for CBF development in small water bodies.
- Conduct an assessment of the lessons learnt from previous CBF projects.
- Incorporate risks of climate change and variability in CBF programmes.

5.6.2. Reduce the threat of impacts of cultured fish release to open waters on wild varieties

Possibly 80–90 percent of all species cultured in the region are not highly domesticated. Inbreeding and small level of broodstock capacity means that wild stocks remain a source of genetic material. Stocking open waters with large quantities of hatchery reared fish can threaten this resource. Impacts on the genetic quality of wild stocks have been identified in a number of wild species in the region (e.g. marine shrimp, silver barb, carps, catfish).

- Effective genetic management of broodstock for hatchery stocks that are to be released into open waters.
- Risk assessment for open water stocking.
- National inventories on wild stocks resources that are targeted for aquaculture.

5.7. Promote aquaculture as an attractive livelihood

Aquaculture presents considerable opportunities to diversify rural livelihoods – especially in staple, crop-based farming systems that are becoming economically uncompetitive due to their small-scale and relatively low value of staple crops. Aquaculture intensification can offer a more competitive farming strategy that could maximize the productivity of small land units. However, there are risks and constraints associated with the intensification or diversification of small farm systems and these require specific targeted policy, financial and technical assistance. The following actions are recommended:

- Document productive, profitable and sustainable intensified aquaculture systems in the region.
- Create an enabling environment for the development of the sector (national/private sector).
- Pay particular attention to the organization and empowerment of small-scale farmers (e.g. servicing via farmer clusters).

5.8. Increase the resilience of farmers in coping with climate change impacts and natural disasters

Climate change and climate variability are affecting aquaculture in the Asia-Pacific region. This is seen as increased vulnerability to storm damage, flooding, and unseasonal water shortage. As aquaculture intensifies, so does investment and concentration of assets, increasing the risk of catastrophic loss and consequent adverse impact on livelihoods. Aquaculture also has an obligation to reduce its contribution to greenhouse gas emission and improve its energy use efficiency. Aquaculture also has the potential to contribute to the generation of renewable energy. The following actions are recommended:

5.8.1. Reduce the vulnerability of farmers to risks and increase their coping capacity

- Governments to explore possible mechanisms to provide insurance and credit services equivalent to those available to other sectors, to support intensification.
- Use risk mapping for vulnerability to natural disasters – especially flooding, coastal storms and drought.
- Assess aquaculture systems for their resilience and how farmers adapt to different kinds of risk.

5.8.2. Seek to capture opportunities that may be presented by climate change

- Aquaculture opportunities may arise through environmental changes such as salinization, and coastal inundation, which degrade agricultural land but offer potential for aquaculture production.
- Improve the energy use efficiency of aquaculture systems and its contribution to mitigation of greenhouse gas (GHG) emissions.
- Government support for energy use efficient systems (e.g. aerators, feeding machines).
- Support for alternate sources of energy for use in aquaculture (e.g. establishment of wind farms in high energy coastal areas).
- Explore the potential of aquaculture products as biofuels (e.g. seaweeds, microalgae).

5.9. Facilitate trade and marketing of aquaculture products

The intra-regional market is becoming important for the trade of seed, feed and fish. Inter-regional markets are important for a limited number of commodities (principally shrimp, tilapia, striped catfish). Since the majority of production is still utilized domestically, there is strong potential for intensified production to creating surplus, leading to gluts and subsequent dumping. There is a market linkage between white fish from aquaculture (e.g. tilapia, striped catfish) that compete in the global market with wild marine capture fishery products (cod, Pollack etc.). In countries with significant inland fisheries (e.g. Cambodia), seasonal or periodic abundance can also result in depressed prices, and this market instability undermines sustainable intensification. Cross border trade between large producing countries can undermine local aquaculture seed and grow-out operations. Markets and prices, therefore, impact and constrain the economic potential for intensification. The following actions are recommended:

- Quantify post-harvest losses, or lost opportunities/value in aquaculture.
- Review infrastructure constraints that limit markets.
- Look at value chains – especially or business opportunities (research/development (R/D), action research).
- Invest in market research and market development.
- Look for the opportunities offered by developing niche products and selling positive ecosystem benefit stories.

- Address consumer misconceptions – seek ways to inform and increase consumer awareness in market countries.
- Intensification should aim to lower the cost of production (cycles of over and under production).
- Recognize the difference between urban (high income) and rural consumers and target intensification support to address consumer preference, needs and purchasing power.

5.10. Promote aquaculture certification as a driver for sustainability of aquaculture industry

Certification plays an increasing role in driving demands for sustainability. This is exerted through a range of mechanisms such as public certification, third party certification as well as the responsible sourcing arrangements of buyers. The latter is probably the principal driver. The following actions are recommended:

- Support national efforts to develop public aquaculture certification schemes (national).
- Raise awareness of and assist governments to make use of the FAO Guidelines on Aquaculture Certification.
- Strengthen national regulatory processes to address key dimensions of food safety and environmental impact.
- Strengthen cooperation with buyers for promoting certified products.

Part II Extended Summary of Thematic Presentations

1. Aquaculture Sustainability Towards 2030

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Just twelve years ago, there were six billion people on this planet. Now we are seven billion, and according to estimates of the United Nations, global population will reach 9.3 billion by 2050 and exceed 10 billion by the end of the century. With hunger and malnutrition identified as a devastating problem facing the world's poor, the challenge governments and international development communities need to address, given the steep population growth, will be to ensure adequate food for all. To provide food to the world's population in 2050, it has been estimated that agricultural output, primarily from crops, livestock and fisheries, including aquaculture, must increase by 60 percent.

Meeting this target is indeed a formidable challenge for the international community, considering that an alarming number of people still suffer from hunger and poverty. Hence, finding opportunities to alleviate poverty and increase food security through agriculture, including fisheries and aquaculture, is vital and timely. Although the future forecasts look grim for global food production, the contribution of fish to global diets has now reached a record of about 17.6 kg per person on average, supplying over three billion people with at least 15 percent of their average animal protein intake. It has been estimated that in 2012, the annual per capita fish consumption will be around 19.2 kg.

In the annual State of World Population Report 2010, the United Nations Population Fund (UNFPA) has challenged the international development community that instead of asking questions like, "Are we too many?" we should instead be asking, "What can I do to make our world better?". International development agencies could provide leadership and more assistance to increase production through expansion and sustainable intensification of the aquaculture sector, which will ease the formidable demand for global animal proteins in the coming decades. (Dr Babatunde Osotimehin, Executive Director, UNFPA, State of World Population Report 2010).

What made aquaculture the world's fastest growing food industry? Several key factors have helped drive growth in the aquaculture sector. These key drivers include the fast growing market demand at local, regional and global levels, improvements in infrastructure, transport, processing and logistics, technical, human and institutional capacity, as well as new investment. The availability of natural resources and the social contribution of the industry, in poverty alleviation, employment generation and food security, have also contributed to aquaculture's rapid growth.

Since the mid 1990s, aquaculture has increasingly driven growth in world fish production as global capture production has leveled off. Aquaculture's contribution to total world fish production has climbed steadily from 20.9 percent in 1995 to 40.3 percent in 2010. By 2030, aquaculture production is projected at 211 million tonnes, representing a share of 58 percent of total supply. Will the supply be enough to feed future population?

Given that population growth is highest in Asia and Africa, where per capita fish consumption is lower than other regions, world per capita fish demand is projected to decline from 17.8 kg in 2007 to 16.6 kg in 2030 even if every country maintains its per capita consumption at the 2007 baseline level. Nevertheless, the fish supply-demand gap is estimated at 51 milllion tonnes by 2030, with the largest gap in Asia (29.8 million tonnes).

These projections indicate a clear need for a larger supply of fish to feed the growing population, but in reality, the aquaculture sector growth rate is slowly declining. How will humanity bridge the supply-demand gaps?

In order to stimulate growth in the aquaculture sector, formidable challenges must be overcome, including land and water resource availability, cost and energy efficiency, ecosystem impacts, continuing dependence of feeds on fishmeal and fish oil, biosecurity and health, environmental policy, technological advancement and the investment climate. Cost- and energy-efficient production systems will be essential to a robust aquaculture sector, and use of renewable energy and low carbon emission systems will become increasingly critical to sector sustainability. Among these, supply of feed is likely to represent one of the most important constraints, with fishmeal and fish oil considered crucial sources of both energy and essential fatty acids in aquaculture feeds. Major research efforts are under way to reduce the level of fish meal and fish oil in feeds and find alternatives to fish and fish oil in aquaculture, thus reducing the industry's dependence on marine resources.

Revenues lost due to diseases in aquaculture are estimated to be in the range of US$5-6 billion per year. With increasing frequency of epizootics and emerging diseases around the world during recent years, improved surveillance and health management in aquaculture at all levels are, therefore, urgently needed. Increasing biosecurity, appropriate biotechnology and breeding of resistant strains, strengthening national veterinary and quarantine capacity all need to be undertaken at both national and regional levels, in order to prevent transboundary transmission of pathogens.

Other areas requiring critical action to enhance sustainability of aquaculture include the need to ensure equitable distribution and hunger reduction; improving efficiency in small-scale aquaculture and empowering small holders, increased production of non-fed species for food security and fed species for income generation, and development of new species with superior qualities and/or consumer acceptability of GMO fish.

Despite these numerous and critical challenges, intensification of aquaculture is inevitable in the face of increasing demand, limited land areas, and improved technology. Whether we are able to accomplish this in a sustainable manner will depend on global governance and stewardship as much as on technological progress.

2. Feeds and Feeding: Problems and Plausible Approaches in Intensification and Attaining Sustainability

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The world demand for seafood is projected to increase by 30–40 million tonnes by 2050, with the bulk supplied from aquaculture. It is, therefore, not surprising that issues of intensification and sustainability are becoming increasingly pivotal. Moreover, much of this additional supply will have to come from the Asia-Pacific region. Very high degrees of intensification have been successfully accomplished in the case of several aquaculture species exemplified by striped catfish (*Pangasianodon hypophthalmus*) and penaeid shrimps, and all evidence indicates these are sustainable, barring fluctuations to be expected in any form of primary production. However, it is critical that future intensification is planned and implemented in compliance with globally accepted norms of sustainable development as originally envisioned by the 2000 Bruntland Report, "Our Common Future".

Improved feed management represents a critical component in the sustainability equation, and the industry's responses, particularly in respect to the use of fish meal and fish oil, will determine whether feeds are likely to become a limiting factor in attaining sustainability. The paper discusses plausible means of reducing dependence on these commodities as well as other avenues for intensification and sustainability.

Globally, around 25 percent of the marine fish catch, approximating 25 million tonnes, is utilized for fish meal and fish oil production, giving an approximate conversion of 5:1 and 110:1, respectively. Aquaculture uses nearly 63 percent and 85 percent of global fish meal and fish oil production, respectively. The leading producers are South America and Europe. Increasingly, in the Asia-Pacific region, fish meal and fish oil are produced using fish processing waste, thereby reducing the need for imports of fish meal by the animal husbandry and aquaculture sectors. Their use in aquaculture feeds has long been controversial since Wijkstrom and New coined the term 'the fish meal trap" to highlight the dependence of aquaculture on marine wild stocks. A further objection was made on ethical grounds, arguing that reduction of a raw material (fish in this case) to produce fish meal and fish oil in order to produce a higher quality luxury animal foods is not ethical. The controversy has sparked a global dialogue and much research into reduction of the use of fish products in feeds. Of the 63 percent of global fish meal supply used in aquaculture, nearly 80 percent is used for salmonid, shrimp and marine fin fish culture- all high-value species, but collectively representing less than 15 percent of global aquaculture production.

Is availability of fish meal and fish oil likely to hinder intensification and sustainability of aquaculture in the Asia-Pacific region? Trends in aquaculture in the Asia-Pacific region suggest that its intensification and sustainability are unlikely to be constrained by fish meal and fish oil availability. For example, in the past decade the major growth in production is attributable to low trophic species such as striped catfish (Viet Nam and elsewhere), *Labeo rohita*- rohu in Myanmar, and tilapia (in many countries in the region); all these require low protein feeds and hence minimal quantities of fish meal and often no fish oil in feed formulations. It is expected therefore that usage of fish meal and fish oil will become more rational as prices rise, and will tend to be used most for high-priced commodities such as the salmonids.

Secondly, the trend towards use of fish processing waste has reduced the demand for fish meal and fish oil. Thailand produces 500 000 tonnes per year of fish meal from trash fish and fish processing (mostly tuna) waste. In Viet Nam the stripped catfish sector generates 500 000–700 000 tonnes of processing waste from which oil is extracted for industrial purposes and the meal used for animal production, thereby releasing the availability of an equivalent quantity of fish meal for aquaculture development. Also, some of the developing countries in the Asia-Pacific region (e.g. India, Sri Lanka, Lao People's Democratic Republic, Viet Nam etc.) apply non-fed practices in their culture-based fisheries; utilizing low trophic species relieves the use of fish meal usage in these systems.

It is, therefore, suggested that fish meal and fish oil availability are unlikely to act as a major constraint to intensification and sustainability of aquaculture in the Asia-Pacific region. Nevertheless, there is a continued need to reduce dependence on these commodities. A number of plausible alternative strategies should be considered. First, among all the researches undertaken on a variety of plant-based raw materials to identify substitutes to fish meal as a feed ingredient, only soy bean meal has achieved any degree of commercial success. Secondly, feed formulations should be revised in light of results demonstrating that at least for tilapia and carp species, the most cost-effective dietary protein level is significantly lower than previously claimed to result in the highest growth rate. According to these studies, using lower protein content feeds the stock grow slightly slower, but are compensated by improvements in focal conversion ratio (FCR) and Protein Efficiency Ratio (PER); the lower protein ration was most cost-effective.

The concept of "mixed feeding schedules" was developed by De Silva (1985), primarily based on the observations on the daily variation in apparent dry matter and protein digestibility of feed in the Asian chromid *Etroplus suratensis* (Bloch). The basic hypothesis was that when the fish were provided a high protein diet throughout the rearing period it might not be able to utilize the feed effectively to the same degree, day after day. This hypothesis has been tested on many tropical species by numerous authors in the laboratory. Based on this hypothesis, many mixed feeding strategies have been tested in a number of aquaculture environments. Data from trials using striped catfish farmers in the Mekong Delta, Viet Nam showed that although harvest time per cycle was 180 days as opposed 210 days for the mixed feeding schedules, saving on feed costs with the mixed feeding schedule ranging from US$20 000–24 000/ha/cycle, far outweighing the delayed in harvesting time. Moreover, nitrogen and phosphorus in the effluent is significantly reduced, making mixed feeding more environmentally friendly.

Culture-based fisheries (CBF) are a much-overlooked and environment-friendly means of facilitating intensification and sustainability in the Asia-Pacific region. According to FAO, the developing nations in Asia have approximately 66 710 052 ha of such water bodies suitable for aquaculture development.

As regional and global demand for food fish increases, it will be imperative that the sector in the region maintains its growth momentum. In order to continue to contribute to global food fish supply, the sector will have to intensify and do so within globally accepted norms for long-term sustainability.

3. Marine Capture Fisheries as a Source of Food for Aquaculture in the Asian Region

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How much of Asia's marine fishery catch is directed to aquaculture? Production of low value/trash fish species in the South China Sea region is estimated at over 8.3 million tonnes. The proportion of total catch varies according to area, but consistently exceeds 20 percent of overall catch, and is considerably higher for the trawl fisheries (typically in the range 40–60 percent). Onshore demand for trash fish is booming, due primarily to aquaculture demand, keeping many operations profitable despite the impact on fisheries.

Demand for captured fish in East Asia's coastal aquaculture is estimated at 1.44 million tonnes for carnivorous fish, and 0.44 million tonnes for lobsters, crabs, and carnivorous mollusc species. The majority of these operations are fed with low value/trash fish from coastal trawl fisheries. Assuming a conversion ratio ranging from 3 to over 6, more than 6.5 million tonnes of fresh fish are required. A large proportion is fed with formulated feed, often containing over 30 percent of fish meal.

An estimated 31 million tonnes of aquaculture production is produced using supplemental or formulated feeds, with fishmeal inclusion ranging from 3–32 percent and conversion ratio of 1–2 kg feed per kg fish produced. This indicates an estimated demand fishmeal demand of 2–3 million tonnes. Asian fish meal is derived from low value/trash fish catch and some small pelagic fisheries, but 56 percent is manufactured from fish processing wastes. Altogether, fishmeal production in Southeast and East Asia is around 988 000 tonnes currently, with Thailand, Japan and China as the major producers.

Thus, 6.5 million tonnes of capture fishery fish are fed directly to aquaculture, and 1.94 million tonnes directed to fishmeal. With 1.1 million tonnes produced in Asia, and 2.18 million tonnes imported, total availability is approximately 3.2 million tonnes fish meal, for a total current fishmeal demand for aquaculture of approximately 2–3 million tonnes per annum.

Asian aquaculture is the world's major user of fishmeal, and 86 percent of fishmeal used in Asia (excluding China) now goes to aquaculture. With no new sources of fish, many argue that we have already reached the limit in coastal trawl fisheries. But, there is a shift away from using fresh fish directly as feed, towards pelleted feeds incorporating fishmeal, which "stretches" it. New fishmeal fisheries are being explored and exploited, such as the Lantern fish in Iran/Oman, the sardine fisheries in India, and Sardinella in the Bali Straits. Some Asian fisheries are already becoming *de facto* "low value/trash fish" fisheries, harvesting specifically to supply aquaculture with feeds. This situation is perpetuated by policies and perverse subsidies, first in aquaculture promotion (low taxes, limited environmental regulations), and secondly in fisheries, where subsidized fuel costs justify trawling for a lower value catch. This means that aquaculture is not paying the 'real price' for its feeds.

The impact on coastal fisheries caused by trawling is attracting increasing attention from critics and environmentalists, and is the source of some conflict within the industry. Diversity is certainly declining, and in terms of resource use, it is probably more efficient to trawl fish to eat, than to trawl for feeds.

All trawl fisheries generate some bycatch. This could be utilized if the trawling was undertaken responsibly. The use of responsibly sourced fishmeal or fish products is included in aquaculture certification standards. For example, the Aquaculture Stewardship Council has already finalized standards for abalone, bivalves, pangasius and tilapia, and is expected to approve standards for salmon, shrimp and trout by the end of 2012, with Seriola/Cobia to follow.

Global GAP's Compound Feed Manufacturing Standard (CFM) stipulates that the species of fish used and their countries of origin must be identified. Proof must also be provided that the feed does not contain species classified as critically endangered or endangered on the IUCN Red List.

Global Aquaculture Alliance (GAA)/Best Aquaculture Practices (BAP) is planning to set new standards after 1 June 2015, requiring that at least 50 percent of fishmeal and fish oil derived from reduction fisheries shall come from approved certified sources, and that at least 50 percent of fishmeal or fish oil derived from fishery by-products such as trimmings and offal shall come from approved certified sources.

The Responsible Fishmeal – IFFO RF Standard requires producers to source their whole-fish raw material from fisheries managed according to the FAO Code of Conduct for Responsible Fisheries (MSC certification is accepted as proof of this). Producers must also avoid the use of Illegal, unreported and unregulated fish (IUU), and there must be no sourcing of fisheries by-products from IUCN red-listed fisheries. Manufacturing must be undertaken under a recognized quality control scheme to ensure product safety, purity and traceability.

Increasing competition for human food and growing fish prices and demand will incentivize more innovative use of low value/trash fish (exemplified by the rising trend in surimi production). Declining catches, combined with innovative use of small bony demersal fish and increased use of icing/preservation, will leave less available for fish meal production.

In conclusion, although most Asian aquaculture is not highly dependent upon fishmeal, the industry will be affected as supplies tighten and costs rise. Increasing scrutiny of sources of fishmeal will also impose increasing compliance burdens on feed manufacturers. The principal impact will be on higher end products, which are most likely to be able to carry the additional costs of alternative ingredients.

4. Sustainable Intensification in Aquaculture Production: Role of Domestication and Selective Breeding

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The Atlantic Salmon, Tilapia and Whiteleg Shrimp (*P. vannamei*) are the most successful aquaculture species. Fundamental to this success has been the success of genetic improvement of the broodstock. Over the past 20 years, the relative genetic gain in growth rate in aquaculture has far exceeded that in livestock, and resulted in farmed populations with faster growth, more efficient focal conversion ratios (FCRs), and higher levels of disease-resistance.

Selective breeding has taken a sustained long-term effort, increasing in sophistication from the earliest attempts at mass selection and cohort selection, to embrace techniques such as marker-assisted selection/quantitative trait locus mapping (MAS/QTL). Breeding of Genetically Improved Farmed Tilapia (GIFT) began only in the 1990s, using eight base populations, four wild (from Egypt, Ghana, Kenya and Senegal) and four farmed (Israel, Singapore, Taiwan Province of China and Thailand). Index selection for five generations in the Philippines from 1990–1996 resulted in accumulative genetic gain of 85 percent. This was followed by 16 generations at the World Fish Center, Malaysia, which brought a further doubling in the selection response. GIFT has since been distributed to 14 countries and accounts for between 30–70 percent of production in Asia.

More intensive aquaculture systems are justified not only for their greater control, reliability or land use efficiency, but also by their enhanced utilization of genetic potential. However, genetic potential does not automatically translate into performance-systems must be selected to realize the genetic potential of the farmed species.

Genetics are also key to increasing sustainable production of shrimps. The change from *P. monodon* to *P. vannamei* was accompanied by intensive selection of *P. vannamei;* yields increased from 11.95 t/ha/yr in 2002 (monodon) to 52.2 t/ha/yr in 2010 (vannamei), while production costs fell from US$5.27/kg to US$2.45/kg. Domestication has allowed shrimp to be put in ponds with a certainty of health, and with known characteristics. It also provides the base for establishing selective genetic programmes. Domestication was not always high on the agenda; PLs from hatcheries were less sought after than wild PLs. PLs from wild broodstock were accepted but those from a captive source would not be.

In 1996 there was virtually no use of domesticated stocks; Hawaii was the first to develop domesticated specific pathogen free (SPF) white shrimp in response to IHHNV in that state. In 2000 the industry in both the Americas and Asia began to convert; in 2002 only 2–5 percent of Thailand's industry used domesticated stocks; by 2005 over 90 percent of shrimp culture were from domesticated sources.

At CP the entire shrimp breeding process is done in a nuclear breeding center (NBC) and is fully biosecure. Broodstock is reared on only pelleted diets, using recirculation systems and health monitoring by polymerase chain reaction (PCR). Key traits that can be enhanced are survival (disease resistance), growth rate, salinity tolerance and reproductive fecundity. Growth rate is highly heritable and is key to cost reduction, FCR, time to harvest and survival. Families with best disease tolerance are selected via challenge testing; as a result of continued selective breeding, Taura virus has been eliminated as a disease issue in Thailand.

As mentioned above, realization of genetic improvement requires control of the pond environment, and sometimes, modification to management practices, especially with regard to biosecurity, oxygen levels, predator/competitor exclusion and pond bottoms. This is only possible under intensive culture conditions.

Overall, domestication and selective genetics have made major contributions to the industry's sustainability and profitability. Clean shrimp mean healthy shrimp, reducing pond failures by preventing introduction of viruses or pathogens. Domestication also allows application of the powerful tool of selective genetics, resulting in higher survival and shorter production cycles. Genetic gains have contributed to annual gains in pond efficiency, translating into lower costs of energy, labour, capital and feed costs, combined with higher annual yields.

CP's vision of sustainability for shrimp is to produce more shrimp from less land, with less energy, with less marine fish inputs, with less feed, with less waste.

5. Carbon Footprint to Move Towards Sustainability

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Carbon footprinting (CF) has emerged as a measurement tool to evaluate the life cycle greenhouse gas (GHG) emissions associated with an organization, product or service aiming to stimulate the reduction of GHGs and to communicate the information of carbon footprint to consumers via carbon labelling. CF assessment is rooted in Life Cycle Assessment (ISO 14040/44) concerning energy and raw materials consumption. To reduce GHG emissions associated with food consumption and production, CF labelling is being introduced for food products in several EU countries and in Asia, in an attempt to reflect the contribution to GHG emissions of consumption patterns and food choices. This mechanism is expected to facilitate the purchasing decision for low-carbon food products by consumers, thus stimulating the development of low-carbon production technology which could contribute to climate change mitigation. By informing and influencing key players along the whole food supply chain (i.e. producers, retailers and consumers), the carbon label strategy is expected to stimulate reduction of GHG emissions at both production and consumption levels.

Recent rapid growth in aquaculture production, especially in developing countries, has stimulated interest in GHG emissions from the sector. Aquaculture is of interest both because it is a major emitter of GHGs due to the intensive use of energy by aerators, and the crop-based/fisheries-based feed ingredients needed. The sector itself is also at high risk of adverse impacts from climate change.

A study of the carbon footprint of individual quick frozen (IQF) breaded shrimp was introduced and the standard PAS 2050 methodology described in outline. At present the PAS 2050-2: 2012 specification for assessment of greenhouse gas emissions from aquatic food products is under development, as well as Product Category Rules of Fisheries and Aquaculture Products in Thailand and Product Category Rules of Seafood Products in Japan.

The study pointed out some methodological considerations and offered practical recommendations to assist in standardization. For example, close attention needs to be paid to establishing system boundaries, e.g. for frozen shrimp products, the energy used at point of sale should be included, but human labour such as for peeling shrimp should be excluded. To compare various shrimp products, weight can be used; but when comparing among aquaculture/fisheries products, the product unit could be a specific weight of whole body, edible protein or nutrient depending on the grouping of products with similar characteristics and through the stakeholder consultation process.

Carbon footprint has become a useful tool for GHG assessment and management for climate change mitigation, and is expected to increase in importance, assisting in identifying hot spots for improvement, evaluating performance of different farming systems, comparing new and current products, and selecting appropriate climate-friendly technologies. Comparative carbon footprint values can give an indication of green farming systems as well as climate-conscious products. Application of CF should be promoted in aquaculture and fisheries products to stimulate green food production system and green business.

6. Intensification of Aquaculture in Asia-Pacific: The Case of China

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Asian aquaculture has grown rapidly and been the largest contributor to the growth of world aquaculture production over the past three decades. It now represents more than 90 percent of global aquaculture output by volume. As the world's largest producer and exporter of aquaculture products, China plays a critical role in the global fisheries sector.

Fisheries production and consumption are both predicted to increase due to population growth, income raising and urbanization. With the stagnation of capture fisheries, expansion of aquaculture industry is forecast as the only way to meet the continuing increase in world demand for fisheries products. An increase of 60 percent in global aquaculture production by the year of 2050 is expected to maintain per capita fish consumption at its current level. However, in line with economic growth, urbanization, and changes in dietary habits within the Asia-Pacific region, this target consumption level may also increase across the region. While growth in aquaculture has contributed to food security and rural livelihoods, it has also caused significant environmental disturbance. Facing these challenges, relevant policy actions need to be taken to ensure sustainable intensification of aquaculture.

7. Role of Trade, Markets and Value Chain Management in the Substantive Intensification of Aquaculture: The Case of Bangladesh

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Bangladesh is a prominent aquaculture producing country in Asia, ranked the thirteenth in 2009 among 34 Asian countries in terms of production. At present Bangladesh contributes 7.92 percent of global shrimp production. It was the world's sixth largest producer and seventh largest exporter of shrimps in 2011. However, despite strong growth in production in recent years, shrimp farming faces significant challenges at both domestic and international levels. As a shrimp exporting country, key policy priorities for Bangladesh include increased market access, higher value of production and development of the fisheries sector. This paper discusses some of the major features and dynamics of the shrimp aquaculture sector in Bangladesh relating to trade, market and value chain. This will help identify the challenges and opportunities for the development of the sector. Shrimp aquaculture is selected for study because of its importance for export and employment.

Aquaculture shrimp farming in Bangladesh is carried out mostly under extensive conditions, except for a few intensive farms in Cox's Bazaar. Few inputs and no mechanization are used in extensive production systems. Over 37 000 farms culture *Bagda* shrimp (*Penaeus monodon*) on farms of average size 4.5 ha in brackish water conditions, while there are 105 000 farms cultivating *Golda* freshwater prawn (*Macrobrachium rosenbergii*), with average size of only 0.28 ha. About 60 hatcheries are in operation.

Under semi-intensive and intensive farming, productivity is twenty to thirty times higher than with extensive farming. Although significant natural resources and abundant workforce give Bangladesh comparative advantage in shrimp production but poor management, lack of infrastructure, unavailability of suitable land, quality food and fertilizer and variable weather conditions constitute factors which combine to keep the productivity low.

According to the Bangladesh Frozen Foods Exporters Association (BFFEA) there are 149 shrimp processing factories located in Khulna, Bagerhat, Satkhira and Chittagong. Of these, 88 are licensed by the government to export and 74 have permits to export to the EU.

Within the fisheries sector, shrimp make the largest contribution in terms of foreign exchange earnings. The contribution of shrimps to total export income from fish and fish products increased to 91.1 percent in 2010 from less than 1 percent in 1972–1973. The European Union (EU), the United States of America (USA) and Japan are the major importers of shrimp from Bangladesh, accounting for more than 95 percent of total fish exports. The shrimp sector thus carries strategic importance for the national economy, with the EU market of particular importance. The value chain for the Bangladesh shrimp sector is described in detail.

Following banks on exports to EU and USA due to non-compliance with sanitary and phytosanitary standards, Bangladesh has invested substantially in improving processes and control systems, and exports to EU have now resumed, thanks to several initiatives to ensure better management for shrimp aquaculture and resource management, policy support and strengthening of the regulatory framework. Nevertheless, implementation remains weak. In order to export shrimp, quality control licenses are issued by the Bangladesh Standards and Testing Institute (BSTI) under provisions of the Bangladesh Environment Act 1992 and the Bangladesh Environmental Regulation 1997. Processing firms are required to complete Initial Environmental Examination before their establishment, and to submit an effluent treatment plan and environment management plan to the Department of Environment to obtain Environmental Clearance Certification.

Shrimp processed for global markets has to comply with the international standards specified by Codex Alimentarius Commission provisions as well as buyer specifications and regulatory requirements of the importing country. Unfortunately, Bangladesh has difficulty in meeting with these standards due to insufficient resources. As in the case for other developing countries, there is inadequate public sector capacity to monitor compliance to the required standards. Also, Bangladeshi plants have insufficient funds to invest in expensive mechanical equipment, fishing boats, quality control measures and training staff, and the capacity to design, implement and monitor quality and safety compliance is also very weak. Thus, while concerns of shrimp importers about quality and safety compliance by Bangladeshi plants are reasonably justified, and in principle conform to the sanitary and phytosanitary (SPS) provisions of the WTO, the underlying causes of the country's lack of capacity to address buyers' concerns must also need to be taken into consideration.

In view of the growing importance of shrimp aquaculture the focus should be the overall development through overcoming the constraints identified along the value chain. Efforts should focus on increasing profitability and income from the sector, by: (i) improving governance through proper implementation of institutional policies and rules; (ii) improving access to resources, removing financial and infrastructural bottlenecks; and (iii) enhancing market access through compliance with trade measures and improvement in environmental performance.

8. Planning and Management Tools for Sustainable Intensification of Aquaculture

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Article 9.1.3 of the Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fisheries states in its principles and articles aimed at promoting best practices for conducting fishing and aquaculture that:

"States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities" (FAO 2011).

Ecologically sustainable development (ESD) is a concept that seeks to integrate short and long-term economic, social and environmental effects and values in all decision making (Fletcher et al., 2005). The World Commission on Environment and Development (WCED) defined sustainable development as that which "*meets the needs of the present without compromising the ability of future generations, to meet their own needs*" (WCED, 1987).

A related concept more specifically related to aquaculture is ecosystems approach to aquaculture (EAA), defined by the FAO as an approach that:

"strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems including their interactions, flows and processes and applying an integrated approach to aquaculture within ecologically and operationally meaningful boundaries. The purpose of EAA should be to plan, develop and manage the sector in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by aquatic ecosystems" (FAO, 2006).

The commercial imperative to intensify aquaculture, due to increasing seafood demand and the finite nature of aquatic resources, presents significant challenges to meeting this goal. This said, the needs of the aquaculture industry and societal objectives of sustainability need not necessarily be at odds, particularly in terms of medium and long-term goals of the aquaculture sector. Ecological sustainability is not solely about environmental protection. It is also about long term commercial viability of a sector that can contribute to food security and bring immense socio-economic benefits. Successful aquaculture relies on maintaining healthy aquatic resources and on the surety of long-term rights of access to these resources. ESD-based planning and management tools have the capacity to deliver of jurisdictional responsibilities for ensuring the sustainable intensification of aquaculture, both in terms of meeting environmental objectives as well as proving industry reliable access to high quality aquatic resources. This paper describes the range of aquaculture planning and management tools that can make up a government jurisdiction's planning and management framework for achieving sustainable intensification of aquaculture.

A jurisdiction's regulatory activities aimed at meeting its ESD objectives for aquaculture fall into five core areas of responsibility: (1) To mitigate environmental impacts; (2) To minimize socio-economic impacts and optimize benefits; (3) To ensure food safety and quality; (4) To manage biosecurity risks (pathogen, pest and genetic risks) associated with aquaculture; and (5) To manage animal welfare. The planning and management tools needed to meet these responsibilities are applied at various points along the aquaculture supply chain, which can be broadly divided into three components:

- site selection and construction,
- production (including harvesting), and
- post-harvest processes (including transport, processing and sale).

Public sector tools for planning and managing aquaculture under the above-mentioned five areas of responsibility range from broader licensing and regulatory enforcement systems to specific management tools guided by principles such as ESD and EAA. The tools are discussed under four broad categories: (1) Environmental and socio-economic risk management tools; (2) Food safety and quality; (3) Biosecurity; and (4) Animal welfare.

Environmental and socio-economic risk management tools include aquaculture zoning according to biological carrying capacity, environmental impact assessment (EIA), controlled allocation of farm sites, farm licensing systems, farm audits and monitoring programmes.

Food safety and quality tools include food safety risk assessment, monitoring and control of farm inputs, residue testing, shellfish quality assurance programmes and traceability systems designed to address current and emerging food safety risks.

Biosecurity covers three main areas of concern: pathogen or disease risks, pest (or invasive species) risks, and genetic risks. Tools within this category include quarantine, health certification, disease surveillance and early warning systems, farm reporting/audits, and emergency preparedness and response systems.

Animal welfare focuses on adoption of three animal welfare standards for farmed fish which are now reflected in the Aquatic Animal Health Code of the World Organization for Animal Health (OIE), namely, standards for transport; stunning and killing for human consumption; and killing of fish for disease control purposes.

These specific tools are supported by a range of broader cross-cutting system capacities needed by any jurisdiction to fulfill its responsibilities with respect to ensuring ESD and thereby, the sustainable intensification of aquaculture. These include legal instruments, standard operating procedures, capacity (infrastructure and resourcing, including financial resourcing), and capability (expertise) necessary to implement the specific tools. The single most important tool necessary in all instances is the political vision and leadership to create an environment where the long-term commercial benefits of ESD-based resource management underpinned by good governance are recognized by regulators and the aquaculture industry alike.

9. Small Farmers: Better Practices and Challenges in Moving Towards Sustainability

F.B. Davy & C.V. Mohan, Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand

The activities covered in this presentation form part of regional efforts in India, Thailand and Indonesia in moving aquaculture towards more sustainable farm practices.

The European Commission, under the 7th Framework programme (FP7) Cooperation Theme 2: Food, Agriculture, Fisheries and Biotechnologies, is funding a project the "*ASEM Aquaculture Platform*", coordinated by Ghent University and involving nine participating European and Asian organizations. Its aim is to develop a strong 'Community of Practice' to reconcile ecosystem and economic system demands to promote and consolidate sustainability in aquaculture development in both regions. NACA will play a key role in the project's planned initiatives, including leading Work Package 2, "*Development and validation of commodity-specific Better Management Practices (BMPs) for smallholder farmers in the Asia-Pacific region*". This work package focuses on promoting wider adoption of BMPs for key aquaculture commodities in NACA member countries, thereby contributing towards sustainability of this important food production sector and improving livelihoods of small farmers. The focus is on assessment of the impact of BMP implementation and developing scale-up strategies at national and regional levels. This report summarizes our detailed assessment of recent work on the impacts of shrimp BMP programmes, including technical, social, economic and environmental dimensions, in the Asian region. Challenges and opportunities for scaling up are also identified.

Cluster farming is introduced as one such opportunity, involving collective planning, decision making and implementation of crop activities by groups of farmers organized as a cluster, using a participatory approach to accomplish their common goals (reduce risks, maximize returns, and move towards sustainability). A successful example of the potential of cluster development is offered by the National Center for Sustainable Aquaculture (NaCSA) experience in India. NaCSA is scaling up and now has over 700 clusters, many of which have formed cross-linkages for knowledge sharing with other clusters and extended linkages to other sectors (e.g. milk, pineapple and other fruit) and across Asia (e.g. Thailand, Viet Nam, and Indonesia). Such networks might be expected to offer important support to small-scale farmers in meeting the new challenges presented by a global marketplace. Clusters are expected to facilitate access to credit and insurance, give voice to farmers in policy debates, and help farmers meet increasingly stringent compliance burdens.

The example of the Sam Roi Yod shrimp farmer cooperative in Thailand was also presented as a success story involving local and European partners. The cooperative established and operates an Internal Control System (ICS) and maintains records for internal and external audit. It has already reached compliance with the Thai Good Aquaculture Practice (GAP) standards as well as the requirements of the buyer (Marks & Spencer). Its produce is exported to the EU and reaches a higher price than would be possible in the domestic market. Fair Trade Certification is also now in process.

In Aceh, Indonesia, a major post-tsunami reconstruction initiative has been under way, including rehabilitation of the aquaculture sector, supported by various donors under the *"Build Back Better*" programme. The initiative is based on BMPs and the cluster management approach, and testing a number of farmer support mechanisms. Four Aquaculture Livelihood Service Centres (ALSC's) have been established in Bireuen and Aceh Utara, and a specialized Aceh Aquaculture Communication Center (AACC) provides advice and information services for the new ALSCs. An Aceh Development Society (ADS) has also been set up. To date, over 2 000 participating small farmers are farming shrimp and milkfish. Market links to Japan and the United Kingdom are being established, and Fairtrade certification is in progress.

The NaCSA experience in small-scale farmer innovation parallels lessons learned in other sectors. The experience leads us to a broader perspective on issues- for example in regard to who and what should change, as well as a shift towards new approaches to organizational change, the role of clusters as farmer support mechanisms, network organizations, private sector partnerships, and new links across value chains as well as vertically (local, national, regional and international levels).

In conclusion, the evidence shows that if farmers can see benefits, particularly long-term benefits, they will change their farming practices under a variety of conditions and drivers. With provision of adequate support and services ("hand holding" combined with an expanding toolbox) they can be part of the solution in moving aquaculture towards sustainability. Continued broad-based research is suggested to document these processes, capturing and sharing lessons learned including organizational lessons.

10. Promising Aquaculture Practices for Sustainable Intensification

Peter Edwards, Asian Institute of Technology, Bangkok, Thailand

The challenge of feeding nine billion people is three-fold: to meet the food demand of a fast-growing and more affluent population; to do so in environmentally and socially sustainable ways; and to ensure the world's poorest people do not go hungry. Given natural resource limits, technological change and intensification will be required to maximize productivity and optimize across a complex land (water) scape of production, rural development, environment, social justice, and food consumption outcomes. The concept of sustainable intensification emerged in agriculture, faced with limited potential for increase in area of terrestrial crops and livestock. Aquaculture, the third and relatively underdeveloped food producing sector, has already seen exponential growth over the past 15 years, especially in Asia, and has a great potential to expand on both land and water in most Asian countries contributing significantly to food and nutritional security, livelihoods and poverty alleviation, and economic growth. Lessons have been learned from disastrous losses e.g. through disease epidemics, caused by unfettered and unsustainable over-exploitation of aquatic resources. The challenge for sustainable intensification of aquaculture will therefore be to develop resilient systems to accomplish these outcomes whilst minimizing adverse environmental, food safety and social impacts.

A range of technologies shows promise for increasing productivity in key systems in inland and coastal systems. Many of them link traditional and modern practice to reduce cost of production and adverse environmental impact of modern pellet-fed aquaculture and the integrate systems to treat effluents.

The continuing poverty faced by vast numbers of traditional small-scale aquaculturists attests to its inadequacy as a major livelihood. Farmers need to intensify to secure their livelihoods. Many such traditional systems are suited to low-cost diversification, using improved seed and direct/indirect indole-3-acetic acid (IAA) feed as a first step on the ladder of intensification. Indirect agriculture-aquaculture integration and/or use pelleted feed offers a second route with huge potential, especially in fewer developed Asian countries.

Whilst the importance and potential of rice/fish culture is grossly overestimated, conversion of rice paddies to fish ponds can yield much higher returns (e.g. in the Red River Delta, Viet Nam) especially when stocked with high quality juveniles. Moreover, Asia has an estimated 67 million ha of small community-owned water bodies constructed mainly for irrigation, creating a huge potential for culture-based fisheries. The feed value of aquatic macrophytes such as water spinach is under-appreciated but has finally been recognized by FAO.

Other promising technologies for pond intensification include modern polyculture, Biofloc and diffuse aeration. With the highest recorded agricultural commodity production in the world (400–600 tonnes/ha/8 month crop in Viet Nam), sustainable intensification of *Pangasiid* catfish aquaculture offers a glimpse of the potential productivity improvement. In these operations are environmentally sustainable as ponds are flushed by the Mekong River, and nutrient loading from catfish ponds is minor compared to that from agriculture, industry and human settlements, and within the carrying capacity of the Mekong River and the South China Sea. There is a huge potential for adoption in Myanmar as Ayeyarwaddy Delta has abundant water and soybean could be grown in-country as feed.

Use of inorganic fertilizers to 'green' ponds or reservoirs can reduce feed costs in tilapia and pearl production, supplemented later with pelleted feed, whilst in aquaponics systems, effluents from intensive tank culture of tilapia fertilize terrestrial vegetables on floats. Biofloc systems are suited to intensive culture of fish and shrimps. Addition of low-value carbohydrate-rich supplementary feed, combined with aeration produces protein-rich bioflocs can reduce feed requirement by 30 percent.

Recirculation aquaculture systems (RAS) are useful for producing high-value species in which good environmental control or high biosecurity is required (e.g. specific pathogen free (SPF) shrimp, barramundi nursing) or where land or water are scarce or expensive, and for public aquaria. Where water is scarce, partitioned aquaculture systems can potentially reduce water usage per unit of fish by 90 percent, as well as facilitating management and harvest. Promising technologies for cages include low-volume high-density (LVHD) cage culture, cage-in-pond culture systems and integrated freshwater cage aquaculture.

Examples of promising technologies for sustainable intensification include the 'landscape approach' for small-scale farmers with shrimp ponds integrated into intertidal zone to maintain ecological functions of mangroves, and closed re-circulation ponds constructed on an industrial scale, located above the inter-tidal zone to help eliminate problems of disease and effluent.

Integrated multi-trophic aquaculture (IMTA) offers a new approach that integrates pellet-fed finfish with inorganic extractive seaweeds, organic extractive mollusks and benthic detritivores, e.g. sea cucumber, either in open water or as land-based systems. Such systems were first developed in China as first seaweeds, then scallops and later finfish cage culture were sequentially developed on commercial scale in coastal bays. IMTA is still at the experimental stage and more research is needed on carrying capacity. Closed marine systems and land-based IMTA is also mainly experimental, but has been commercialized in Israel.

In conclusion, although there is no panacea on the horizon, there is a huge potential to increase Asian aquaculture productivity through wider dissemination of existing technologies, especially in less developed countries. It seems unlikely that RAS and offshore cages will be adopted in Asia in the near future due to their high cost and complexity. Also, significant reduction of nutrients in intensive pond and cage aquaculture effluents remains an elusive goal. Greater implementation of BMPs will improve efficiency of existing systems, and EAA will contribute to more appropriate integration of aquaculture with other land uses, and to preserving environmental integrity.

11. Sustainable Intensification of Aquaculture Value Chains: Perspectives from an EU FP7 Research Project

David Little and Francis Murray, Institute of Aquaculture, Stirling University (Sustaining Ethical Aquaculture Trade Project), Stirling, United Kingdom

Over the past decade aquaculture has seen its focus transform rapidly from domestic demand to global trade. Initially driven by the shrimp trade, the pattern is repeating for white fish species such as pangasius and tilapia. As the scale of the transformation impacts on production systems and markets in developing countries all around the world, it is therefore important to understand the sustainability implications for the producer countries and for destination markets in Asia and Europe. With the growing focus on sustainable intensification of aquaculture to meet food and nutritional security needs, there is a need to explore whether farmed seafood from Asia can truly meet Europe's growing demand for 'sustainable' products. To address these and related questions, it is necessary to examine the dynamics of the whole value chain to identify the winners and losers, to assess the resilience of increasingly intensive production systems in Asia, and the capacities and limitations within farmed seafood value chains. From the market perspective, we also need to make an assessment of the current market in Europe. Is European demand stable? Will it continue to grow, and what are the implications for wild stocks?

Identifying useful boundaries for assessing sustainability is a challenge. Global value chains link production and consumption of farmed seafood across continents and a growing international trade increasingly substitutes for diminishing and inconsistent supplies from wild stocks. Several factors challenge the sustainability of aquaculture in tandem with its rapid rise to the importance in supporting aquatic food security.

Modern commercial aquaculture systems remain relatively open to their immediate environments and are increasingly dependent on distant sources of feed and other inputs because they are resource intensive. The openness or porosity of production systems raises issues of both pathogen exclusion and biodiversity impacts. A key issue is the level to which isolation from the 'environment' is possible or desirable. Strategies to manage interactions to achieve a balance between the needs of the production system, the species farmed and the integrity of the environments that support them are presented and discussed. Pressures on water and land resources are forcing both intensification and stimulating integration, although these may be contradictory approaches. Tracing sustained seafood supplies to availability of basic nutrients and energy suggest the vulnerability of emerging aquatic food production systems. The challenges of meeting energy and nutrient needs in the coming decades will stimulate emergence of ever more efficient systems but competitiveness with other sectors of food production will be critical.

The EC FP7 research project SEAT (Sustaining Ethical Aquaculture Trade) is using Life Cycle Analysis as a core tool to assess the broader impacts of aquaculture on the global environment, allied to detailed modelling of local environmental impacts. In addition, aspects of particular importance such as water use and social and economic impacts require assessment both local to production and along the value chain. The ethical dimensions and contradictions of Asian production systems based on trade with Europe are considered with reference to the shrimp and tilapia value chains in China and the Pangasius farms in Viet Nam.

12. The Role of the Private Sector in Sustainable Aquaculture

Dan Fegan, Regional Technical Manager, Aquaculture, Cargill Animal Nutrition, Thailand

Cargill, founded by William Wallace Cargill in 1865, has grown from a single grain elevator in Conover, Iowa to a highly diversified, privately-held global business composed of 71 businesses organized around four major segments: Agriculture, Food, Financial, and Industrial. Today Cargill has 139 000 employees in 65 countries.

As a global food and agricultural company, sustainability is critical to Cargill's businesses, and we are involved in a range of stewardship activities to support responsible use of natural resources. Our innovative approaches to conserve resources, use renewable raw materials and reduce impacts are aimed at helping to protect and preserve our environment. Examples include our support for the Palm Oil Round Table and Responsible Soy Initiative, in collaboration with a variety of partners such as WWF, The Nature Conservancy, Global Aquaculture Alliance (GAA), the Aquaculture Stewardship Council (ASC) and the Sustainable Fisheries Partnership (SFP).

Aquaculture is a dynamic industry, and Cargill participates along the entire supply chain, supplying inputs, finance, technical support and information services. Cargill Animal Nutrition is at the heart of the supply chain and works hand-in-hand with many other Cargill businesses. For example, we often work with our grain and oilseeds businesses in sourcing raw materials, and with our animal protein businesses to develop technology and industry best practices. We also work with our processing businesses to identify co-products and additives that can be applied to the animal nutrition space. Our most significant challenge is how to deliver appropriate nutrition to meet expected performance at an affordable price?

Designing successful aquafeeds is a complex task requiring consideration of a wide range of factors aside from nutritional factors. Successful feed formulation depends on the needs of the species, the needs of the market, non-nutrition needs (such as price, pellet quality, color, smell, aggressive feed intake), nutritional profile, effective use of ingredients, technological, regulatory and cost constraints, and maintenance of high quality standards.

With the ratio of world feed grain stocks to use at a 38-year low, and unprecedented volatility in feed ingredient prices, the stakes have never been higher, and with increasing sophistication in buyer demand, aqua feed formulation is certainly an ongoing challenge. When choosing feeds, farmers typically present a number of buying signals. First, there is a prevailing popular belief that high crude protein (CP) is a guarantor of high quality, whilst in fact, nutritional value is driven by digestible amino acids and amino acid balance present in the formulation. With regulations specifying minimum CP levels, use of cheap or indigestible protein or non-protein nitrogen to satisfy CP expectations is growing.

Second, farmers want the feed to smell or taste fishy, even for herbivores and omnivores, requiring the incorporation of fishmeal or fish oil. Similarly, pellet colour is important, with markets varying in their preferences for pellet colour (dark or light). These two factors constrain ingredient and formulation choices.

A third factor is that farmers like to see fish fighting for feed, since this suggests a strong preference for a particular feed. Removing or reducing fishmeal reduces this behaviour, and additives have limited success or are too expensive. Adoption of alternative ingredients is constrained by one of more of these factors: Impacts on feed quality (appearance, smell, taste, water stability, fines); impacts on feed function (attractability, palatability, acceptability); and impacts on nutrient availability (digestibility, nutrient imbalance, anti-nutritional factors).

Intensification of aquaculture will be driven by a combination of technological, market and economic factors. Sustainability is an especially important consideration in aquaculture investment, in particular where external financing is required. Sustainability standards and certification provide reassurance for investors but these tend to apply mainly to exported products. Establishment of national regulatory mechanisms is fundamental to underpin and manage sustainable intensification, but needs to be carefully understood in order to avoid unintended consequences.

Intensification and sustainability are not mutually exclusive but can be developed as a "win-win" strategy. The challenge will be how to structure aquaculture development to allow adequate investment and economies of scale with appropriate safeguards of sustainability and food safety within a smallholder-based industry.

Part III Extended Summary of Country Papers

1. AUSTRALIA: Sustainable Intensification of Aquaculture – Country Status Paper – Australia

Ramesh Perera, Director, Aquatic Animal Biosecurity, Department of Agriculture, Fisheries and Forestry, Australia

Aquaculture is a relatively new industry in Australia, and has grown in volume at an average rate of approximately 12 percent per annum since 1992–1993. In 2008–2009, the industry was worth in excess of AU$887 million. Most of the value of Australian aquaculture production comes from high value species such as pearls, salmonids and tuna but over 40 species are commercially produced. In terms of value, the top five aquaculture species groups include Salmonids (AU$356 million), pearl oysters (AU$104 million), southern bluefin tuna (AU$102 million), edible oysters (AU$99.6 million) and prawns (AU$77.5 million). The industry mostly operates in near-shore or land-based sites within the coastal zone. Aquaculture production systems include land-based shallow ponds, freshwater dams and controlled environment indoor tanks inland or in coastal regions, as well as offshore cage culture. Aquaculture producers must comply with strictly enforced federal, state and local government laws and codes of practice, aimed at ensuring best practice and the industry's long-term sustainability. Australia's national strategy for aquatic animal health (AQUAPLAN) is now under review. Similarly, AQUAVETPLAN is the Government's aquatic animal disease emergency preparedness mechanism.

As part of the Australian Government's development of the country's first ever national food plan to ensure long-term food security, the aquaculture sector will play a key role and will be subject to new measures to enhance its efficiency and resilience in order to meet the Plan's objectives to mitigate risks to food safety and security, enhance competitiveness, sustain the natural resource base, reduce barriers to market access and contribute to economic prosperity, employment and well-being.

Increasing urbanization and competing land uses have led to the establishment of Aquaculture Development Areas (ADAs) in order to secure the industry base. Western Australia has invested AU$2 million to establish two aquaculture zones. South Australia currently has 11 approved aquaculture zones, with another two underdeveloped. ADAs streamline the environmental approvals processes to attract investment.

Concerns over intensification of production are being addressed in a number of ways. Environmental modelling is under way to create a better understanding of mechanisms, impacts, and mitigating measures, whilst some States have developed Sustainable Aquaculture Strategies. These strategies include review triggers at a regional level to consider the cumulative impacts of aquaculture developments.

Moreover, a number of mandatory tools are applied to monitor trends and manage aquaculture intensification. All aquaculture operations must be licensed, and any plans for intensification must be approved by the relevant Department. Aquaculture developments must also implement management and environmental monitoring plans. Some states also impose mandatory reporting requirements for production and environmental modelling.

Australian aquaculture has decreased in volume, but grown in value over the past decade. Production was valued at AU$870 million in 2009–2010. Most aquaculture developments are small-scale operations, although the overall number of aquaculture permit holder numbers is stable, consolidation is occurring in sectors such as mussels and abalone.

The ongoing attrition in Queensland is attributable to significant environmental constraints and restrictive legislation for new and existing aquaculture developments in coastal waters adjacent to the Great Barrier Reef Marine Park World Heritage Area. A new state planning regime is soon to be implemented which is expected to place significant restrictions on future aquaculture development.

Australian aquaculture faces a range of constraints to intensification, including a restrictive regulatory environment grounded in environmental concerns. Public acceptance is low because aquaculture is widely considered to be a major polluter of coastal areas through sediment, nitrogen and phosphorus loads despite scientific evidence to the contrary. Moreover, there are limited areas of State waters sufficiently deep for offshore aquaculture, and Commonwealth legislation contains no provision for aquaculture developments in Commonwealth waters.

A number of measures are proposed for sustainable intensification of aquaculture, including sustainable aquaculture strategies and lease zoning plans for marine waters in NSW; increased R&D and extension to increase understanding of environmental impacts, environmental capacity, biosecurity and aquatic diseases; risk management and capacity building for aquaculture operators; and marketing plans. Most importantly, sustainable aquaculture needs to be promoted as an environmentally sustainable alternative to commercial fishing.

The black tiger prawn is presented as a success story in sustainable intensification of Australian aquaculture. Developed over the past ten years by CSIRO and prawn farmers, the new Australian black tiger prawn has the potential to increase national production from 5 000 to 12 500 tonnes per annum by 2020 and boost the industry's value by AU$120 million, based on the current production area.

2. BANGLADESH: Sustainable Intensification of Aquaculture in the Asia-Pacific: The Bangladesh Perspective

Md. Goljar Hossain, Deputy Director, Department of Fisheries, Bangladesh

The mandate of the Department of Fisheries (DOF) covers six key areas: extension, resource conservation, quality control, policy advice, socio-economic development and capacity building.

Fish production increased from 2 440 011 tonnes in 2006–2007 to 3 061 687 tonnes in 2010–2011, representing an annual growth rate ranging from 4.9 percent to 7.3 percent per annum over this period, culture fisheries grew significantly, and by 2010–2011 accounted for 47.7 percent of total national production. In contrast, the contribution of capture and marine fisheries (which together contributed 78 percent of total production in 1983–1984, has declined considerably, and accounted for only 52 percent of total production by 2010–11. In 2010–2011 the total aquaculture area covered 627 731 ha.

Fisheries accounts for 22.21 percent of agricultural sector gross domestic production (GDP), and 4.43 percent of national GDP, and is a key to food security, representing 60 percent of animal protein intake in the country. Per capita fish consumption has increased from 12 kg per annum (1983–1984) to 18.4 kg per annum. The sector also employs over 1.5 million people, In 2010–2011 exports of fisheries products jumped sharply from under 80 000 tonnes in 2009–2010 to a record 96 469 tonnes in 2010–2011.

A National Fisheries Policy was established in 1998, with 5 objectives: to enhance production, reduce poverty by improving livelihoods, meet growth in animal protein demand, stimulate exports, and maintain ecological balance/biodiversity. The policy is implemented via eight development strategies, overseen by DOF. Other concerned stakeholders include NGOs, community-based organizations (CBOs), private sector service providers and other government agencies.

Key production challenges in Bangladesh aquaculture include shortages of feed ingredients, high production costs, lack of technical knowledge, and slow export growth. The shrimp subsector, which grew from 128 000 tonnes in 2005–2006 to 185 000 tonnes in 2011–2011 and by a spectacular 18.6 percent from 2009–2010 to 2010–2011, faces an additional challenge of vector-borne diseases.

Following the launch of the National Fisheries Strategy in 2006, a programme of institutional innovation has been initiated to address these challenges. This includes the MCS Plan for marine fisheries, a district-wise production plan, intensification of aquaculture in the floodplain, a plan for expansion of cage culture, and a Citizen's Charter was also adopted in 2008. New legislative measures include the proposed Shrimp Policy (2010), the Fish Feed Act (2010) and Fish Feed Regulation (2011), Fish Hatchery Act (2010) and Fish Hatchery Regulation (2011), the ban on piranha fish, and the draft Fish Sanctuary and draft Fish Quarantine Acts.

These measures, coupled with the recent emergence of specialized regional 'aquaculture hubs' have led to a major boost in production. Aquaculture hubs have been established in Jessore Region (spawn/fry/fingerling production); Trishal, Mymensingh (pioneers in commercial production of pangus); Doudkandi Model, Comilla (commercial aquaculture in semi-closed water bodies (flood plains) by community-based fisheries management (CBFM); and Cox's Bazar, Khulna, Bagerhat, and Satkhira, which have seen phenomenal growth in shrimp culture area and production.

With a climate conducive to aquaculture, Bangladesh has a significant potential for intensification. Since 1989, productivity grew from 874 kg/ha to 2 152 kg/ha (2010–2011), and today at least 25 aquaculture technologies have been adopted. With most of current production consumed fresh, there is a major potential for processing, either by icing or drying. Productivity enhancement will depend on healthy

reliable supplies of spawn/fry and fingerlings. Recognizing this, the National Fisheries Policy prioritized the establishment of a Brood Bank and government hatchery, and also encourages private hatchery development.

Challenges for sustainable intensification range from shortages of quality fry, fingerlings and feed, high input costs, and lack of access to technology by farmers. These production challenges are exacerbated by post-harvest losses, weak market support and credit mechanisms, and the emerging impacts of climate change. The combined impact of unregulated intensification results in the degradation of ambient water bodies and environmental damage.

Priorities for sustainable intensification of aquaculture include strengthening research to identify appropriate location-specific technologies and to mitigate climate change impacts; reduction of post-harvest losses, and policy support to improve farmer access to credit and market infrastructure.

Some promising progress has already been accomplished in moving towards sustainable intensification. In 2010–2011 Bangladesh fishery production and exports reached a record 3.06 tonnes; and the country achieved self-sufficiency in shrimp and carp seed production. In 1998, Bangladesh received the Edward Sawma Award (FAO) for popularizing fish culture in rural undrainable ponds, and the CGIAR 2004 Award for institutionalizing CBFM.

3. CAMBODIA: Country Status and Success Story on Sustainable Intensification of Aquaculture

Hav Viseth, Director of Aquaculture Department, Fisheries Administration, Cambodia

Fish is vital to the well-being and livelihoods of millions of people in Cambodia, for whom fish is their major protein source. Cambodia has the most intensively exploited inland fisheries in the world, with an annual production between 300 000 and 450 000 tonnes. At present, the harvest of wild sources of fish and other aquatic species cannot keep pace with the demand presented by the country's growing population. Aquaculture is under increasing pressure to fill this gap. Over the last ten years, aquaculture grown by an average 10 percent per annum. Nevertheless, capture fishery still dominates, with aquaculture at present contributing only 12 percent of the country's total fish production.

Freshwater aquaculture predominates, and culture systems include pond culture, paddy fields and floating cages. However, the majority of farmed fish is derived from inland cage culture, estimated to account for more than 50 percent of total production. The sector is overwhelmingly dominated by small-scale producers. In 2011, aquaculture provided full-time or part-time jobs to about 60 000 households.

More than 25 species of freshwater fish are cultured; 60 percent are indigenous and the rest has been imported and domesticated for many years. *Pangasiid* catfish is the most important cultured species, in both cage/pen and pond culture, which has the highest production. The *Clarias* catfish is also preferred as it grows faster than native species. Other popular cultured fish species include silver barb, climbing perch, tilapia and Chinese carps.

In order to secure the country's future fish supply, the Cambodia Fisheries Administration has published a Strategic Planning Framework (SPF) for Fisheries (2010–2019), which projects annual production growth of 15 percent to 185 000 tonnes by 2019.

Cambodian fisheries are governed by the Fisheries Law (2006), with the Department of Aquaculture Development (DAD), Ministry of Agriculture, Forestry and Fisheries, charged with developing and managing the aquaculture sector, and for promotion of aquaculture development. Its work is supported by two aquaculture research centers (Bati Fish Seed Production and Research Center and Chrang Chamres Fish Seed Research Center) and by the country's universities.

Issues and constraints to sustainable intensification include inadequate or inconsistent policies, lack of access to good quality seed, inputs and finance, inadequate knowledge of induced breeding and larval rearing methods for indigenous fish species preferred by local people, weak extension services and lack of reliable water supplies.

Future research and project design must focus on addressing local socio-economic conditions and needs as well as technical issues. In order to accomplish national economic and food security goals, Cambodia needs to develop a strategic aquaculture sector plan that would assure the availability of good quality seeds through breeding, promote access to modern hatchery technology and genetic improvement methods, and improve feed use efficiency. Moreover, extension, institutions, output market chains and research all need to be upgraded.

Innovative approaches such as participatory fish culture development and farmer-based extension have met with some success in helping building farmer knowledge to address their challenges through collective effort. Seed availability has increased as a result, and more households are able to obtain fish for consumption on a regular basis. Some farmer leaders have become innovators and have contributed significant new knowledge to solve local problems without awaiting external technical input. Examples

include hatchery designs modified to suit local needs at least cost, as well as seed nursing and fish culture techniques that will bring down the cost of production are the best examples. Recognizing the role of women in aquaculture, there is also an increasing emphasis on the need to ensure female participation in all activities, especially training programmes. The active participation of women has contributed significantly to improving efficiency as well as sustainability of aquaculture operations.

4. CHINA: Standardized Ponds Reconstruction in China: Contributing to Sustainable Intensification of Aquaculture

Wang Dan, Direct Clerk, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China

Pond aquaculture is China's the most important and common aquaculture system. In 2011, the area of pond aquaculture reached 2.86 million ha. Productivity of pond aquaculture is relatively high compared with other systems; in 2011, pond aquaculture production reached 19.4 million tonnes in 2011, accounting for 48 percent of total production, although it covered only 37 percent of the total aquaculture area. Common farming species include carp, catfish, tilapia and shrimp.

However, progressive intensification of pond aquaculture has brought a number of threats to sustainability. The ponds were originally designed and constructed during the 1980s to meet the needs of traditional or semi-intensive aquaculture. Three decades later, farmers increasingly encounter major problems such as collapsing bunds, silting up, blocked pumping and drainage channels and inefficient power supply systems. Productivity and competitiveness suffers as a result; ponds in such poor condition cannot compete with modern intensive systems. Moreover, aside from the impact on productivity and produce quality, such systems present increased environmental risks. The majority of the breeding facilities and equipment built during the 1980s are unable to withstand the increasing severity and frequency of natural disasters. In 2011, losses in the aquaculture sector attributed to natural disasters were estimated at US$4 billion.

Moreover, the increasing population pressure and urbanization have led to decline in the total aquaculture area, imposing further pressure on the remaining area to intensify in order to meet China's growing demand for fish protein.

The Government of China has recognized these constraints and acknowledged the need for urgent action to ensure long-term food security and economic sustainability of the sector. In order to safeguard the health of aquaculture environments and boost productivity, the government has launched a number of major programmes. Over 2 600 Healthy Aquaculture Demonstration Farms using basic best practice have so far been built. Also, an aquaculture certification system, aquatic stock breeding programme, and an anti-epidemic surveillance system including diagnostic laboratories and pathogen library have been established. Quarantine for fry is now mandatory.

From 2008, the central government allocated funds from its agricultural modernization development fund to support pond reconstruction in coastal cities using standardized designs. By 2010, over 700 000 ha of ponds had been reconstructed, and the Twelfth Five-year Plan of National Fishery Development has set a pond reconstruction target of 1.3 million ha by 2015.

In order to meet this target, each year the central government selects 450 aquaculture farms with culture area of 15 ha or more to carry out reconstruction of pond infrastructure. Selected farms are eligible for financial support of up to RMB25 000–50 000 (US$4 000–8 000). So far, about US$70 million have been invested in the programme. Although funding cannot reach all farms, the scheme represents the beginning of a long-term government-financed transformation of the sector.

Provincial governments are supporting reconstruction by publishing pond reconstruction plans and allocating reconstruction fund in annual budgets. The recommended designs for freshwater and marine pond reconstruction include waste water discharge standards. For example, Jiangxi Province has given financial support of approximately RMB15 000 (US$2 400) per hectare to aquaculture farms located near Poyang Lake.

Nevertheless, despite these major efforts of the government, the farm size remains an obstacle to progress because the vast majority of aquaculture farms in China are small family-run operations, without the resources to upgrade and modernize their production systems, facilities and equipment. In order to address this, the government is promoting the consolidation of land holdings to create larger production units. The central government permits voluntary transfer of land-use rights by farmers, with a range of mechanisms for cooperative operation. Some farmers transfer their land-use rights to the village collective or a large company and earn rents. The village collective or the company can then organize production on a larger scale, with contiguous ponds. Other farmers join cooperative organizations using financial support from the government and raise reconstruction funds to renovate their culture facilities and equipment.

The redesigned ponds are already paying dividends in terms of increased efficiency and productivity. The standardized designs reduce water usage, improve land use productivity, and allow higher culture densities due to the more easily controllable environment and water recirculation system. As a result, these systems discharge less pollution and offer greater resilience to diseases and natural disasters, as well as improving productivity through intensification of production. The pond reconstruction programme has brought significant environmental benefits as well as long-term sustainability and resilience to climate change impacts.

5. INDIA: Present Status and Prospects for Indian Aquaculture – An Overview

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India is the second largest cultured fish producer of the world with aquaculture production exceeding 4.1 million tonnes during 2011–2012. Total fish production for 2010–2011 reached 8.288 million tonnes, comprising 5.068 million tonnes from inland fisheries and 3.220 million tonnes from marine fisheries. Since the early eighties, the sector has seen phenomenal growth, attributed mainly to adoption of scientific fish culture technology including composite fish culture and integrated fish farming. The inland fisheries sector registered an eleven-fold growth during the past 60 years, propelling the country to the forefront of the world's fish producing nations. India today ranks third in the world for fish production, and is the world's second largest producer of inland fish. The fisheries sector is a direct or indirect source of livelihood for over 14.19 million people in India. With increasing domestic demand and changing dietary habits, coupled with stagnation in the marine sector, aquaculture faces strong pressure to intensify to meet projected future demand.

The sector is already responding to these forecasts. Indian seafood exports have grown exponentially over the past five years; in 2010–2011 exports were valued at US$2.86 billion, and are projected to reach US$4 billion in 2011–2012 (SEAI, 2011). There has been a comprehensive development of hatcheries for shrimp seed production, feed mills for shrimp feed, ancillary industries in aquaculture engineering, drugs and chemicals, marketing, processing and export activities. Over 300 000 jobs have been generated in the primary and supporting sectors.

However, despite these accomplishments only one third of the inland water area (850 000 ha) available for aquaculture has been brought under scientific fish culture. In freshwater systems, major impediments to development include low quality of seed and inputs, low market value of carps, low farmer incomes, disease and water availability. In contrast, coastal aquaculture has grown, based solely on culture of shrimp for export. Nevertheless, emerging disease outbreaks have taken their toll. Unfettered development of shrimp farms by the private sector has led to social and environmental issues. Moreover, without even basic infrastructure (roads, electricity, communication and even drinking water), shrimp operators face serious challenges in reaching compliance with increasingly stringent sanitary and phytosanitary (SPS) requirements imposed by importing country buyers, governments as well as the World Trade Organization (WTO). Rejections have risen as a result.

India also has yet to respond to increasing global environmental concerns regarding the use of fishmeal in aquaculture feed, as well as impacts on mangrove forests. Overall, there is a serious lack of biosecurity systems, as well as in regulatory provisions to promote aquaculture development following socially and environmentally sustainable principles.

These environmental challenges, coupled with the growing gap between supply and domestic demand for aquaculture products, underscore the need for sustainable intensification of aquaculture production in India. A number of opportunities to contribute to this goal are evident. With the acknowledgement of the threat to agricultural productivity represented by declining groundwater resources, recharging the groundwater table is recognized as an urgent need. Thus, ponds and impoundments constructed for rainwater harvest can also be productively used for fish farming with virtually no loss of water, resulting in dual benefits. In this regard, pond renovation is urgently required at national level to ensure adequate holding capacity and depth of ponds, which will improve productivity as well as enhance aquifer recharge. Promotion of modern aquaculture technologies will further contribute to both goals as well as help preserving environmental integrity. Moreover, there is a considerable potential for further productivity improvement through *in-situ* modification of farming systems through species diversification breed improvement and system upgrading.

Species diversification will be a priority: at present freshwater aquaculture in India is dominated by carp which contributes 82 percent of total aquaculture production. Since carp is a low-value fish, introduction of high-value species such as minor carps, barbs, freshwater prawn, murrels, catfish, etc. will contribute to improve livelihoods as well as increase resilience of the system to the species-specific market fluctuations and pathogens. Polyculture and system diversification offer additional means of diversifying risk and increasing income.

Since broodstock is one of the most critical determinants of final productivity, breed improvement underpins all the above system improvements and represents an essential prerequisite for exploiting the genetic potential of aquaculture species, improving productivity and increasing resilience to pathogens. Gamete cryo-preservation has already been used in India with some success in India to improve broodstock for quality seed production. The technique may also be significant in relieving the shortage of quality seed and fingerlings in the country.

As feed typically constitutes more than 60 percent of production costs, ensuring availability of quality feed ingredients and formulated feed will also be essential to realize the potential of aquaculture operations. Despite the clear productivity benefits, use of concentrates to achieve a balanced diet has yet to be widely adopted due to cost factors.

Fish farming is a capital-intensive operation enterprise, but access to capital for aquaculture development remains constrained by perceptions of high risk among banks and venture capitalists. Policy interventions including affordable insurance schemes are needed to stimulate investment in the sector.

Finally, prevention of environmental and social impacts will be a key to long-term sustainability of the sector. Such impacts may be avoided or mitigated by sound planning, using Geographic Information System (GIS) as a basis for zonation based on ecosystem carrying capacity. Technology too can help mitigating or remediating environmental impacts, for example via bio-remediation and microbe mining in ponds to reduce levels of organic carbon, nitrogen and phosphorus in aquaculture ponds.

6. INDONESIA: Country Status of Indonesian Sustainable Aquaculture

Tatie Sri Paryanti, Head, Aquaculture Data and Statistics and Lazuardi Fachrul Nizar, Programmeme Cooperation Division, Directorate General of Aquaculture, Republic of Indonesia

Over the last ten years, Indonesia's aquaculture production has shown phenomenal growth, at up to 24.5 percent per annum, from 1.14 million tonnes in 2002, to 7.93 million tonnes by 2011. Fisheries policy is increasingly focused on aquaculture, owing to the continuing decline in capture fisheries resulting from over-exploitation. More than 80 percent of production comes from small-scale farms, with over 1.5 million farms registered in 2011. Today, aquaculture is set to assume a growing economic significance due to the demands of a growing population and increasing protein consumption in the diet.

Production systems in fresh, brackish and marine waters are diverse, and include pond culture, tambak, cage, raft, and paddy-field culture. Freshwater pond and tambak culture are dominated by shrimps, milkfish, tilapia, carps, and catfish and remain the fastest-growing food production sector.

The government aims to accelerate sector development through sustainable intensification in order to meet projected growth in domestic and global market demands. Efforts will focus on increasing productivity, added value, competitiveness, farmer income, and labour absorption. In 2010 an Integrated Aquaculture-Business-Centre Zone was established as a first step, aiming to provide an industry service platform covering the entire supply and value chain from upstream to downstream. This project is supported by the Ministry of Marine Affairs and Fisheries in collaboration with local governments and stakeholders, and now operates in more than 100 districts.

Sustainability in aquaculture operations is fostered by a range of measures, including socialization of sustainable aquaculture through applying good aquaculture practices in accordance with international regulations such as Codex of Alimentarius (CODEX) and World Organization for Animal Health (OIE), certification for hatchery and grow-out operations, introduction of organic aquaculture and development of energy-saving systems e.g. catfish and seaweed production. A number of management tools are applied including risk analysis, health certification, quarantine, residue inspection and monitoring, record keeping and traceability, input quality assessment and monitoring, production process and farm management tools. Indonesia is also in the course of planning a disease surveillance and early warning system.

A number of issues constrain progress towards sustainable intensification of Indonesian aquaculture. Perhaps most challenging is the fact that the vast majority of producers are very small-scale household operations. With low levels of education, technical skills and access to capital, farmers are resistant to change, particularly as there is no price premium for GAP-certified produce, and their ability to sell all their produce in local markets.

Broodstock and seed quality remain low, imposing a major constraint to productivity improvement. Although genetic improvement has been successful in a few species, much more remains to be done to reduce dependence on wild resources and improve fish health management, which is poorly understood by farmers. Greater attention is needed in the areas of water quality and disease monitoring, use of chemical drugs, probiotics, vaccines and other materials, in order to enhance product quality and safety without compromising environmental integrity.

Climate change brings major implications to fish farmers, affecting the availability and quality of water sources as well as its potential for habitat destruction. However, as small-scale producers are generally preoccupied with day-to-day survival, there is a low level of awareness and community participation in environmental protection activities.

In order to address these challenges and accomplish a sustainable trajectory for intensification of Indonesia's aquaculture sector, the following needs should be prioritized. First, a wider access to high-quality seeds and broodstock through local government hatchery units will be a prerequisite to sector development. Secondly, there is an urgent need to implement the government's fish health management programme, particularly the surveillance and early warning system. Thirdly, in order to alleviate feed shortages and high costs, the government should also facilitate development of farm-made feed formulations using local raw materials. Fourthly, development of low trophic level-based polyculture systems, together with technologies to produce low-waste feed will contribute to sustainable intensification and minimize environmental impacts. Finally, aquaculture facilities should be redesigned to respect the local environmental carrying capacity.

Seaweed farming is considered a major success story in Indonesia, contributing to a range of development objectives, including creation of livelihoods in coastal areas, poverty alleviation, fulfilling domestic and export demands, providing raw material for value-added products (e.g. carrageenan and agar-agar) as well as biofuels, and stimulating local and regional economies. Seaweed farming uses no fertilizer, feed or chemical inputs, and also serves as an effective CO_2 sink. Culture can be combined with tiger shrimp or milkfish in polyculture systems. Seaweed farming in Indonesia grew by 30.5 percent from 2010 to 2011, with production reaching 5.2 million tonnes in 2011.

Similarly, catfish offer advantages for low-impact aquaculture, since they can be cultured in a range of systems, have modest water requirements, and can be cultured at high densities of up to 100 fry/m^2. Catfish require no pond aeration, and waste water can be used to fertilize adjacent paddy fields. In paddy-fish systems, catfish also consume some paddy pests. They are also suitable for polyculture, e.g. with tiger shrimp, and for paddy/fish-shrimp rotations.

7. LAO PEOPLE'S DEMOCRATIC REPUBLIC: Status of Aquaculture in Lao People's Democratic Republic

Thongkhoun Khonlaliane, Department of Livestock and Fisheries, Ministry of Agriculture and Forestry, Lao People's Democratic Republic

Capture fisheries and aquaculture in Lao People's Democratic Republic are based on water resource ecosystems mainly consisting of rivers and streams, hydropower and irrigation reservoirs, diversion weirs, small water bodies, flood plains and wet-season rice fields. The total area of water resources for capture fisheries is believed to be more than 1.2 million ha. The estimated consumption of inland fish is approximately 167 922 tonnes per year while consumption of other aquatic animals is estimated at 40 581 tonnes per year. Most of the consumption is from internal production (i.e. imports are of minor importance), so these figures represent approximate catches or yield of the fisheries. These estimated yields are conservatively valued at almost US$150 million per year.

The Lao people, especially in the rural communities which account for more than 75 percent of the population, still depend upon the country's fish and other aquatic animals as their most reliable sources of animal protein intake. The estimate of actual fish consumption per capita (kg/capita/year) of inland fish is 24.5 kg, while other aquatic animals account for about 4.1 kg and marine products around 0.4 kg, to make a total of 29 kg of fish and aquatic products consumed per capita per year.

As aquaculture expands, many forms of production system are being developed, for example pond culture, communal ponds, rice-cum-fish culture and cage culture. Such forms of production systems are divided into sub-categories depending on the nature and main activity of the producers. According to the Department of Livestock and Fisheries (DLF), in 2007 aquaculture production accounted for 54 750 tonnes in an area of more than 42 000 ha, including cage culture in the Mekong and some tributaries.

There has been a significant increase in the recent years in intensive Tilapia production using cage culture (MRC Technical Paper No. 5, April 2002). Culture of Tilapia in floating net cages in the Mekong River and irrigation reservoirs has emerged in the last two years, with one enterprising farmer establishing approximately 360 cages (Thavone Phommavong, 2010). Constraints for large-scale development of Tilapia cage culture include lack of extension services to advise farmers, along with an inadequate supply of high quality fingerlings.

8. MALAYSIA: Sustainable Intensification of Aquaculture in Malaysia

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Unlike its neighbours in the Asia-Pacific region, Malaysia does not have a long aquaculture tradition. The industry began during the 1920s, with an extensive polyculture of freshwater fish in ex-mining pools, followed by marine shrimp culture in trapping ponds. Subsequently, bottom culture of cockles and extensive culture of freshwater fish in earthen ponds were introduced in early 1940s and mid 1950s. During the 1970s, the industry was boosted by the introduction of semi-intensive shrimp culture methods, as well as by floating net cage culture of marine finfish, followed by the raft culture of green mussels. In early 1990s the establishment of government and privately owned fish and shrimp hatcheries as well as private feed mills further stimulated sector growth.

Under the 3rd National Agriculture Policy (1998–2010), aquaculture in Malaysia entered a new era whereby sustainable intensification aquaculture was promoted through large, integrated High Impact Projects (HIP) established within Aquaculture Industrial Zones (AIZ) on over 130 000 ha of suitable land and water bodies. Open-sea cage culture and tank culture with recirculating aquaculture system (RAS) were among new technologies introduced at the time. The emphasis on sustainable intensification is further strengthened under the current Agro Food Policy (2011–2020) through implementation of 3 entry point projects (EPPs) under National Key Economic Area (NKEA) programme. Ongoing large-scale projects include seaweed culture, integrated cage culture (iCAGE) and integrated shrimp culture (iZAQ). In 2010, there were 10 383 ha of cockle farms, 285 540 m^2 of mussel raft culture, 364 908 m^2 of oyster raft culture, 1 988 744 m^2 of marine and brackish water floating cages, 7 722 ha of brackish water ponds and 182 097 m^2 of tanks for marine aquaculture throughout. Seaweeds, cockle, white shrimp, seabass and tiger prawn represented the major cultured species for marine and brackish water aquaculture while freshwater catfish, river catfish, red tilapia, black tilapia and giant snakehead were the major species for freshwater aquaculture.

In 2010, Malaysia produced over 2 million tonnes of fish with a value of MYR9.495 billion (US$ 3.1 billion). Production from the aquaculture sub-sector including seaweeds reached 581 048 tonnes with a value of MYR2.8 billion (US$916 million). In addition, the ornamental fish industry produced almost 342 million live aquarium fish valued at MYR14.47 million (US$4.74 million); in total fisheries contributed 1.3 percent to national GDP, with 0.4 percent from aquaculture. The industry also created jobs to 129 622 fishermen and 26 291 fish culturists.

Aquaculture has been identified as an engine of growth, with a critical role in ensuring national food security, and is expected to bridge the projected gap between demand and supply due to population growth and depletion of capture fisheries. The 3rd National Agriculture Policy (NAP3, 1998–2010), sustainable aquaculture development was identified as a priority. NAP3 led to the establishment of the Aquaculture Industrial Zone, whose main objectives are to create permanent areas for aquaculture projects, encourage private sector participation and provide livelihoods. The NAP3 was replaced in 2010 by the NKEA scheme under the new Agro-Food Policy (2011–2020). Twelve NKEAs were set up to implement EPPs covering integrated seaweeds farming, finfish culture and shrimp culture.

Despite a well-established and comprehensive legislative and regulatory framework for aquaculture, weaknesses and loopholes remain in regulation of the industry. The GAP code remains voluntary, and EIAs are mandatory only for operations requiring the clearing of more than 50 ha of farming area. Under a recent institutional cooperation agreement, Norway will provide expertise and training to assist in upgrading Malaysia's regulatory framework for sustainable development of aquaculture.

The urgency of this task is highlighted by the continuing deterioration of natural resources: Studies indicate significant decline in mangrove forests from 1989 to 2009, attributed in part to aquaculture. Moreover, statistics show that trash fish is the second largest fraction of fish landings by trawlers. High demand for trash fish for the aquaculture industry will encourage the use of trawl nets, which cause severe damage to the marine ecosystem and depletion of fish stocks.

Other constraints faced by the industry include the challenge of compliance with stringent safety requirements of importing countries, disease problems, and supply of quality seed and feed. The need to combat transboundary diseases is particularly urgent, especially for the shrimp industry. An effective broodstock development programme will help by ensuing specific pathogen free (SPF) stock. Enhanced stock will be more resilient to biotic and abiotic stresses and offer higher focal conversion ratios (FCRs). Reliable artificial breeding techniques are also needed to produce large and consistent volumes of high quality seed required by aquaculture operators.

Sustainable intensive farming technologies and expertise will be needed to support future development of open-sea cage and recirculating aquaculture systems (RAS). Such systems use 99 percent less water, have a low space demand, eliminate the need for antibiotics and chemicals, minimize waste discharge, and prevent fish and parasite escapes.

Finally, effective and cheaper feeds are needed for broodstock, larva, juvenile and on-growing fish, prawn and other aquaculture commodities including those culture under SPF conditions to avoid horizontal transmission of diseases through conventional feeds.

The development of High Impact Project in Aquaculture Industrial Zone (HIP-AIZ) under the 9th Malaysia Plan (2005–2010) is presented as a policy-level success story in driving sustainable intensification of aquaculture in Malaysia. At the micro level, the Synergy Farming of Tilapia Cage Culture in Temenggor Dam, Perak, implemented by Trapia (Malaysia) Sdn Bhd, is held as an example of high-productivity aquaculture that complies with social and environmental standards, and produces a high-value, fully traceable product for domestic and export markets.

9. MALDIVES: Maldives Status on Sustainable Intensification of Aquaculture

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To address the continuing decline in tuna fisheries, traditionally the main source of income for rural island communities in the Maldives, a fisheries sector diversification policy was implemented some years ago, with marine aquaculture or mariculture as one of the key activities. These include pilot scale culture of pearl oysters, seaweed and grouper. Half-round pearls in Penguin shell (*Pteria penguin*) are cultured on longlines; seaweed (*Eucheuma cottonii*) is cultured in nylon bags attached to a line in order to minimize herbivore predation, and grouper (*Epinehelus fuscoguttatus*) is hatchery-produced with broodstock conditioning in floating net cages. However, as yet none of these is producing in commercial quantities. Sea cucumber culture (*Holothuria scabra*), the most important current aquaculture activity, involves hatchery production of seed and rearing of juveniles in semi-enclosed areas of the sea.

The main objective of the mariculture diversification initiative is to increase export earnings rather than to ensure food security. The Mariculture Enterprise Development Project is an aquaculture project currently being formulated by the government with the assistance of the International Fund for Agricultural Development (IFAD). The overall goal of this five-year project is to expand livelihood opportunities and reduce vulnerability of the population.

The main constraints to sustainable intensification of aquaculture in the Maldives are the nascent state of the industry's development, limited expertise and damage to coral reef environments caused by waste from aquaculture operations.

Due to the limited availability of land and fresh water, mariculture is the most appropriate aquaculture system for sustainable intensification. Cage culture of high value marine fish will be an important priority. To establish intensive fish cage culture, Maldives will need to seek technologies and expertise from other countries and conduct collaborative pilot projects either through bilateral cooperation or through the development agencies.

Protection of the coral reef environment, one of the nation's most important assets and revenue earners, and the most important measure of aquaculture sustainability, must be held as a high priority in aquaculture intensification in the Maldives. As knowledge of impacts of intensive aquaculture on coral reef environments remains limited, intensification must be carried out very cautiously.

10. MYANMAR: Trends of Aquaculture in Myanmar

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Fisheries and aquaculture are among Myanmar's most important economic sectors. Together with the livestock sector, they contribute about 7.6 percent to the national GDP. Aquaculture directly employs more than 126 000 direct workers, and indirectly benefits about 630 000 more. Pond aquaculture area has shown growth of an average 36 percent per year for the past decade, from only 64 000 ha in 2000–2001 to approximately 177 200 ha in 2009–2010. Aquaculture production has increased correspondingly, from 120 000 tonnes to 860 000 tonnes over the same period, representing average growth of 14 percent per annum.

Carp and shrimp aquaculture in extend earthen ponds is widespread, covering 86 800 and 89 600 ha respectively. In 2011, the total aquaculture production reached 800 000 tonnes, accounting for 20 percent of total fish production. The main species for finfish aquaculture include rohu (*Labeo rohita*) which accounts for 80 percent of production. Myanmar is the region's top producer of rohu. Other cultured species include catla, mrigal, silver carp, grass carp, big head carp, common carp, striped catfish, tarpian and tilapia. Rohu is favoured due to availability of seed and high demand in both local and export markets. Rohu is produced mostly in monoculture, although there are examples of polyculture using rohu, catla, mrigal, tilapia and common carp.

Commercial farmers carry out carp grow-out in large ponds of 4–20 ha or even larger. These ponds normally are rainfed, with stocking densities of 3 000–6 250 per ha. Farm size varies from 20 to 200 ha. In carp farming, the culture period from hatchling to market ranges from 24–30 months.

Tiger shrimp, whiteleg shrimp (*P. vannamei*) and giant freshwater prawns are cultivated at low stocking densities in extensive culture systems located along large coastal embankments. Semi-intensive culture operations cover approximately 4 000 ha. Mixed culture of carps and giant prawn (*Macrobrachium rosembergii*) is also common, using wild collected juveniles. Mud crab (*Scylla olivacea*) is cultivated to produce soft-shell crab.

To support grow-out operations, a well-developed seed production industry has developed, with breakthroughs achieved in propagation of rohu, common carp, striped catfish, tilapia, tarpian, silver carp and grass carp. However, producion of mrigal, catla and the marine fin fish such as grouper and seabass are more technical in demand and thus less common. Shrimp and prawn seed production has also been undertaken successfully, but its development has been dampened by higher feed costs and the decline in the shrimp market. Currently farmers derive higher net returns from extensive pond culture of tiger shrimp and mixed culture of carps and prawn using wild collected seeds.

Constraints to increasing carp production include difficulties in accessing investment and working capital, price pressure due to a monopoly of exporters, and inadequate value added for exported fish. Therefore, to ensure sustainable intensification of the sector in Myanmar, it will be important to establish licenced aquaculture operations in appropriate zones according to ecological carrying capacity, and supported by essential infrastructure and market support. The government will also need to facilitate access to finance for aquaculture, to enable operators to upgrade and expand their facilities and processes to meet higher standards.

Rohu, Myanmar's most important aquaculture species, is threatened by the accumulation of inbred characters. Rohu broodstock is normally selected from the progeny of the same stock over the years leading to the decline in genetic fitness. With Myanmar's rich aquatic diversity, there is a need to extend R and D to identify potential aquaculture species among indigenous species, and the threats and

benefits of introducing high-demand exotics. Underutilized indigenous species such as mola fish *(Amblephryngodon molar)*, walking cafish (*Clarias* sp) climbing perch (*Anabus testudenous)*, snake head *(Chana spp)* and carplets may present a considerable potential as aquaculture species. Such species are high-value fish with strong domestic demand. Mola fish is also in demand in international markets. However, as yet there are no initiatives for research and development into the utilization of these fish in aquaculture.

In order to develop Myanmar's aquaculture in a sustainable way, mechanisms will be needed for negotiating allocation of water among competing land users, and in ensuring that agricultural pesticides and inorganic fertilizers in adjacent agriculture fields do not pollute fish ponds. Concurrently, there is a need for research into balanced feed formulations for carp and other aquaculture species, to improve culture systems and to disseminate techniques for value addition processes for farmed fish. Such research should prioritize the need for low-cost upgrading and small loans for small-scale aquaculture in rural areas.

Overall, Myanmar lacks an effective system for recording production, complicating the task of compiling accurate records to evaluate species performance and inform policy choices. Thus there is a need to establish such a system nationwide, and improve access to updated market information (production, demand, market forecasts).

11. NEPAL: Sustainable Intensification of Aquaculture in Nepal

Rama Nanda Mishra, National Programme Chief, Aquaculture and Fisheries Development Programme, Nepal

Aquaculture is growing at 8.5 percent per annum and is Nepal's fastest growing food sector. The government has recognized its strategic importance in providing food and nutritional security, employment and improved livelihoods, and in reducing migration. Aquaculture provides direct employment to 97 490 people and contributes 0.5 percent to National GDP and 1.5 percent to AGDP (DoFD, 2011).

Aquaculture in Nepal is limited to inland in the south of the country. Pond aquaculture with polyculture of carps accounts for 87 percent of total aquaculture production. In addition, aquaculture in marginal swamps and cages are also conducted. Monoculture of rainbow trout (*Onchorhyncus mykiss*) in the cooler waters in the northern part of the country is the only successful example of intensive farming practices. However, monoculture of Nile tilapia, African catfish and *Pangassius hypothalamus* has also been started by some farmers recently.

Aquaculture is predominantly small-scale, with an average farm size of 0.28 ha. Nepal has 26 036 ponds and around 25 000 farmers involved in pond aquaculture. The total water area under pond aquaculture is 7 277 ha. Integrated multi-trophic aquaculture is currently promoted by the government. The country aims to improve production by gradually bringing more and more farms under semi-intensive and intensive management practices. Intensive pond aquaculture has doubled from 1 791 ha in 2001 to 3 347 ha in 2011, but remains primarily based on natural food production and supplementary feeding with low cost local feed. Recently, the use of pelleted feed has been increasingly encouraged. Aeration was also introduced, along with stock manipulation and multiple harvesting.

Four years ago, a special programme called "Mission Fish" was launched to offer farmers incentives for area expansion and intensification. Nepal's 'One Village, One Product' (OVOP) programme aimed to scale up trout production has led to expansion of trout culture to 12 districts within five years. The Government's seed management plan and fish seed regulation (under preparation) also aims to regulate seed quality and ensure easy availability of high quality seed for farmers.

Fisheries policy is guided by the 1997 Fisheries Perspective Plan (FPP), a normative and strategic document that provides a 20-year vision for developing the fisheries sector in a sustainable way.

Despite a high potential for expansion and continued growth, sustainable intensification of aquaculture must overcome a number of issues and constraints. Given the continuously growing demand for further intensification and diversification, introduction of new exotic culture species is inevitable, bringing environmental and ecological risks as well as benefits. Proper attention to address environmental and food safety issues will, therefore, be essential along with the monitoring of impacts of climate change.

In Nepal, a number of specific constraints should be addressed in order to accomplish the goal of sustainable intensification. Attention must first be given to appropriate production technologies that limit potential for impacts on environment and biodiversity, especially for the non-native rainbow trout and other carnivorous fish. Carp polyculture is already well-established in Nepal, and would benefit from further R and D including improved feed formulations, genetic improvement and supply of high quality seed. Given that intensification will inevitably bring increased disease pressure, an effective surveillance and early warning system will be fundamental to preventing major ecological and economic losses. Moreover, intensification requires a high level of management, creating a need for capacity building to provide technical assistance to farmers, together with control systems to provide food safety assurance. Finally, an effective quarantine system and other mechanisms must be taken into account to counter threats to aquatic biodiversity from farm escapes.

In view of the special needs of aquaculture, a separate aquaculture policy and strategy is advocated to address the above challenges. This would cover formulation of an Aquaculture Act, Fish Seed Act, and Quarantine Act as early as possible. Similarly, property rights and access to resources should be given legal definition, and a code of conduct established. The policy would also incorporate provisions for genetic improvement and species diversification, promotion of indigenous species, capacity building and support services for farmers, reliable supply of seed, feed and other inputs, and improvements in post-harvest management and marketing. Finally, the absence of finance and insurance for high-risk operations should be addressed, and most importantly, the policy should ensure that the sector is developed with due regard to social issues and the principles of good governance. It is increasingly evident that in the long run, sustainable development and responsible production of aquaculture, can only be achieved with the full participation of producers in the decision-making and regulatory processes.

12. PAKISTAN: Country Status/Paper on Sustainable Intensification of Aquaculture in Pakistan

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Aquaculture in Pakistan is a recent development and in many parts of the country management of the sector remains poor with culture practices varying across the different provinces. Two Asian Development Bank (ADB) projects have assisted in strengthening the institutional structure, with infrastructure development such as the development of hatcheries and juvenile production, model farms, transfer of technology, human resource development as well as the strengthening of extension services.

Extensive and semi-intensive aquaculture systems are practiced in Pakistan. The launch of the First Aquaculture Development Project in 1980–1988 gave major impetus to the industry through the establishment of fish hatcheries. The launch of the Second Aquaculture Development Project in 1990 further strengthened the sector through the establishment of demonstration farms, provision of inputs, technical assistance and extension services.

The fisheries sector contributes approximately one percent to the country's GDP and provides employment for about 1 percent of the labour force. Freshwater carp farming is the major aquaculture activity in three of the country's four provinces (Punjab, Sindh and North West Frontier Province [NWFP]).

Cold water aquaculture provides a unique opportunity in the mountainous areas of northern Pakistan. Two species of trout, namely brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) are cultured in NWFP, AJK and NA provinces.

With the exception of trout culture in NWFP and the northern region, virtually all aquaculture currently carried out in Pakistan is pond culture of various carp species. The main species cultured are rohu (*Labeo rohita),* catla (*Catla catla),* mrigal *(Crihinus mrigala),* grass carp (*Ctenophyrongodon idella),* silver carp (*Hypophthalmichthys molitirix),* bighead carp *(Aristichthys nobilis),* as well as *Tilapia nilotica*, red tilapia and genetically improved farm tilapia (GIFT). Farms range in size from 0.16 ha to 96 ha, with over 6 800 farms and almost 6 400 employed directly or indirectly. Integrated aquaculture (rice and fish culture) is also widely practiced in some areas. The future development of aquaculture is prioritized in the National Medium Term Priority Framework (NMTPF).

Marine and brackish water aquaculture is not practiced in Pakistan, therefore, the government launched the Sindh Coastal Community Development Project to stimulate the development of marine aquaculture to create livelihoods and contribute to the economy. Currently some consolidation is occurring among agriculturists and aquaculturists, with many agriculturists converting their low lying lands to fish farms. Small farmers are turning to operation of mini-fish hatcheries, nursing of hatchlings to fry size and selling the fry through small fish markets.

At this early stage in the sector's development, the government has so far not imposed restrictive measures or taxation on the sector, in order to encourage investment in intensified operations and encourage long-term sustainability. Technical guidance, soil and water tests, and feasibility studies are offered at no cost to the operator. Fish seed is available from government hatcheries at subsidized rates. Training and capacity building are also given at no cost, including costs of accommodation for trainees. The Fisheries Department at district level carries overall responsibility for providing extension services as well as sustainability and intensification.

Issues and constraints for sustainable intensification include the inadequate number of fish hatcheries, and lack of technical assistance in breeding and culture of aquaculture species and fish feed formulation. There is a lack of institutional support for research and training, and laboratory facilities and equipment are inadequate. Overall there is insufficient budget allocation to accomplish policy goals, and to exploit Pakistan's untapped marine resources.

13. PHILIPPINES: Sustainable Intensification of Aquaculture in the Philippines: Status and Success

Prescilla B. Regaspi, Supervising Aquaculturist, Inland Fisheries and Aquaculture Division, Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines

The Philippines is endowed with numerous inland water bodies, including 246 063 ha of swampland, 14 531 ha of freshwater fishponds and 239 323 ha of brackish water ponds, along with many lakes and reservoirs, used for culture-based and capture fisheries production. Climate change, habitat destruction and overfishing have contributed to the decline of capture fisheries. As a result, the availability and affordability of fish for the rural and urban poor has also fallen. Aquaculture is therefore held as critical to sustaining the supply of food fish, as well as a main engine of growth in the agricultural sector. Farmed fish such as milkfish and tilapia became cheaper than poultry and pork and have also replaced marine species of fish in the diet of many.

In 2009, the country ranked the sixth among the top fish producing countries of 5.08 million tonnes of fish, crustaceans, mollusc and aquatic plants, contributing 3.12 percent to global production of 162.8 million tonnes. Aquaculture has seen exponential growth in production since 1991. By 2011, production reached 2.60 million tonnes, of which 71 percent or 1.84 million tonnes come from seaweeds and the remaining 29 percent or 770 000 tonnes from fish, crustaceans and other species. At least 19 species are under marine, brackish and freshwater culture: seaweeds, milkfish, tilapia, tiger prawn, mussel, oyster, carp, mud crab, catfish, white shrimps, mudfish, endeavor shrimps, grouper, siganids, spiny lobster, pompano, abalone, sea urchin and sea cucumber. Seaweed farming is a major livelihood in coastal communities, benefitting an estimated 160 000 families engaged in production or processing. Farming techniques include floating longlines, fixed-off bottom monolines and broadcast method. Farm sizes range from 0.25–10 ha. These mostly small-scale farmers are organized into associations or cooperatives. Production potential is often not maximized due to disease, typhoons and prolonged monsoon rains.

Milkfish has been described as the superstar of Philippine aquaculture. From 1997 to 2011, production has maintained an average annual growth of 6.37 percent. Culture methods range from traditional shallow brackishwater ponds using natural feed (lab-lab) and macroalgae (filamentous green algae) to highly intensive operations. However, intensive systems have faced prohibitively high production costs, reducing market competitiveness. Milkfish are also cultured in freshwater fishpens and cages. Intensive culture in marine cages grew by 36.18 percent in 2011 and is widely practiced within established mariculture park (MP)/mariculture zone (MZ) strategically located on the Pacific and South Western seaboard. Farmed milkfish is marketed and exclusively consumed in the domestic market. Tilapia is the third most important cultured species, with about 95 percent produced in freshwater ponds, cages and pens.

Tiger Prawn has a stable, relatively low level of production of 48 160 tonnes per annum but is nevertheless the country's third largest export commodity. The shrimp industry suffered serious production failures due to disease, and has yet to fully recover. Nevertheless, some farms operate profitably at semi-intensive and intensive levels due to good locations and best farming practices. At present, there are 34 registered shrimp farms producing *Penaeus monodon* and 19 for *P. vannamei,* rearing by monoculture (single crop). There are also 167 registered farms producing shrimps with milkfish, tilapia and other high value species such as siganids. Shrimp monoculture is the most common approach. Registered farms undergo regular residue monitoring for compliance with farmed-based Hazard Analysis Critical Control Point (HACCP) standards. These farms are qualified to supply raw materials for export to certified and accredited processing plants.

A number of factors contribute to low productivity and poor sustainability in the sector, including unsustainable practices, undeveloped mariculture resources, under-productive land-based operations, diseases, genetic deterioration of seed stock (fish and seaweeds), limited availability and high cost of inputs, and resource conflicts in open water. The government has launched a number of development strategies for the sustainable intensification of aquaculture. To address the lack of opportunities and limited skills and technical knowledge of small farmers, a Livelihood Assistance Programme is offered to small-scale fish farmers and seaweed growers to locate operations within MP/MZ. Training is also given to continuously upgrade farmer skills, and strengthen farmer groups in order to access market niche (market matching) as well as participation in trade fairs.

To increase productivity, create employment and generate foreign exchange without compromising the environment, the Bureau of Fisheries and Aquatic Resources (BFAR) has encouraged a shift in mariculture from traditional open-water culture of seaweeds, oyster and mussel to a more intensive approach, integrating resource conservation to manage the resource sustainably. A total of 63 MP/MZ with a total area of about 50 000 ha have been established as community-based marina type projects in municipal waters under the jurisdiction of local government units (LGUs). The locations are directly accessible to external market/foreign trade centers for live fish and value-added product forms. However, these zones are underutilized.

BFAR also aims to increase the establishment of multi-species and community-based hatcheries, which are essential to ensure sustained supplies of quality seedlings for nursery and grow-out culture. At present, there are 18 government-run and 140 privately owned hatcheries, producing of at least 15 species.

BFAR has strengthened its support to the seaweed industry by enhancing production to keep abreast with the growing world demand for carageenan bearing seaweed while providing more livelihood opportunities to coastal communities. The Enhanced Seaweed Production Programme focuses on provision of credit and input assistance, seaweed nurseries, a Seaweed Tissue Culture Laboratory, R and D on genetic improvement of stocks and hatchery and culture techniques, Fish Health Laboratories and continuous monitoring and disease surveillance of 344 registered farms. The programme also provides solar drying facilities to farmer groups.

In 2011, BFAR also launched the Philippine Aqua-silviculture Programme in cooperation with the Commission on Higher Education (CHED). The partnership involves communities in 62 coastal municipalities. Project activities include identification of priority areas, mangrove reforestation, establishment of community-based hatcheries, and training on hatchery operation and aqua-silviculture techniques. The programme aims to arrest and reverse resource degradation due to depletion of natural stocks and reliance on wild stocks for high value species by increasing self-sufficiency.

14. SRI LANKA: Inland Fisheries and Aquaculture in Sri Lanka

K.M.U.K.P.B. Herath, Director, Freshwater Aquaculture Development, National Aquaculture Development Authority of Sri Lanka

Sri Lanka has five major brackish water lagoons and estuaries, with a total water area of 160 000 ha. A total of 261 941 ha of fresh water bodies exist across the country, with over 157 892 ha of perennial reservoirs, 100 000 ha seasonal reservoirs and 4 049 ha of floodplain lakes. Altogether the inland waters have an estimated annual production of 100 000 tonnes of fish. Inland fish production including aquaculture is increasing annually and in 2011 production is approximately 59 560 tonnes.

At present commercial aquaculture in Sri Lanka is dominated by shrimp farming and ornamental fish. Freshwater food fish and marine fish culture are under development and the National Aquaculture Development Authority of Sri Lanka (NAQDA) under the Ministry of Fisheries and Aquatic Resources Development, plays a major role in breeding of freshwater edible fish and freshwater prawn as well as marine fish to meet fish PL, fry, fingerlings and prawn PL requirements. NAQDA also plays a major role through breeding, stocking of fish fingerlings in perennial water bodies, introducing proper management measures and by providing seeds of fish/shellfish to farmers. To broaden diversity and boost industry development, various exotic species have been introduced. Production is today dominated by tilapia, rohu, catla, common carp and cultured shrimp. Brackish-water aquaculture in Sri Lanka is completely dominated by shrimp farming (*P. monodon*).

An estimated 11 000 ha are available for land-based coastal aquaculture other than shrimp, including about 10 000 ha for milkfish culture, 1 000 ha for *Artemia* and 50 ha for crab culture. At present cage culture of sea bass is practiced using imported fish seeds and recently, NAQDA aquaculturists have successfully bred seabass (*Lates calcarifer*) and perfected larval rearing techniques.

At present, intensive shrimp farming is mainly found in the Western, North Western and Eastern coastal belts. However, following the 1996 and 1998 disease outbreaks, the sector was faced with a 90 percent collapse in production and economic losses of up to Rupees 1 billion (US$7.9 million). Recovery has since been slow. The present operating area occupies 1 591 ha, employing about 5 000 people, compared with 40 000 prior to the outbreak. Nevertheless, shrimp is today Sri Lanka's top export commodity, with 2011 shrimp production reaching 4.1 million tonnes.

The ornamental fish industry in Sri Lanka has a long history and started with household-based small-scale outlets. Exports increased with the development of technologies for breeding and rearing of more than 46 species of freshwater ornamentals. Nevertheless, the marine ornamental fish export sector is totally dependent on wild stocks. In 2011, exports of ornamental fish and related product reached Rupees 1.112 billion (US$8.7 million).

Fish seed production is carried out in Aquaculture Development Centers (AQDC), community-based mini nurseries, private ponds and cages. Shrimp seed is produced in hatcheries and used for culture. Wild collection is not practiced, but eggs are obtained from wild-caught brooders and are subject to quarantine prior to introduction to the hatchery. This species is found in the coastal waters around Sri Lanka. No exotic species of shrimp have been introduced up to now. Seed of other important culture species such as sea bass, bivalves, sea cucumber, lagoon crab and ornamentals is also well established in Sri Lanka.

Sri Lanka faces a range of constraints to industry growth and intensification. There are no allocated lands for aquaculture, and insufficient knowledge on value addition and fish processing techniques. Marketing linkages are relatively weak, with poor coordination among government agencies in both marketing and technical aspects. The government dominates in fish breeding, and there is insufficient private sector

participation. As a result, the quality of fish and shrimp seed is inadequate, and more training of technical staff is needed on selective breeding procedures. Intensification is further hampered by the high cost and low availability of inputs such as high quality feed. Lack of enforcement of regulations is also problematic, and violation of crop calendars is commonplace. Finally, there is a lack of basic construction materials for cage and pen culture.

The "Ten-Year Development Policy Framework of the Fisheries and Aquatic Resources Sector 2007–2016", targets an increase in inland fisheries and aquaculture production from 36 530 tonnes (2006) to 132 250 tonnes by 2016. A number of strategies have been prioritized, including fast-track approval of land clearance permits; promotion of private sector participation in farming, fish feed production and processing; introduction of subsidies for pond fish culture; increasing production in minor perennial reservoirs through culture-based fisheries; increase carp production through stock enhancement in major and medium perennial reservoirs; increase the supply of fish seed for stock enhancement by increasing capacity of government AQDCs and construction of mini-nurseries to be operated by Community-based Organizations (CBOs). The plan also calls for strict enforcement of community-based fisheries management in perennial reservoirs, more efficient collection of catch statistics, and promotion of commercial aquaculture through public/private sector participatory demonstration projects. BMPs are to be developed for the main culture systems, and NAQDA field staff strengthened to allow regular monitoring. Finally, the government aims to boost fish seed quality by applying modern broodstock management procedures.

Culture-based fishery in seasonal tanks is considered a success story in Sri Lanka's aquaculture development. There are around 10 000 man-made seasonal tanks covering a total area of around 100 000 ha in the country's dry zone. Fingerlings from different species with different feeding habits have been stocked in these tanks. Gradually, the system has become one of the most popular aquaculture systems, and 2011 production from seasonal tanks was reported as 5 300 tonnes, representing 8.9 percent of total inland fish production.

15. THAILAND: Sustainable Intensification of Aquaculture in Thailand

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Aquaculture activities in Thailand can be divided into two categories: freshwater aquaculture and brackish water aquaculture. Freshwater aquaculture is mainly for domestic consumption. About 78 percent of aquaculture farmer are small-scale. Small-scale freshwater aquaculture remains crucial as a source of food and nutritional security for the rural poor. For the most part, brackish water aquaculture is dedicated to high-value products for export, the most important of which (in terms of annual production), are Nile tilapia, hybrid catfish, prawn and carp. Fish are cultured under various systems ranging from extensive to super-intensive farming for commercial production. Brackish waters along the coast were traditionally used for subsistence fisheries, but this has been supplanted by intensive coastal aquaculture, which has become the most profitable system for farmers. The most important species cultivated are fish such as barramundi and grouper, shrimps, shellfish and crustaceans such as mud crab. This includes both the systematic rearing of the species from the fry stage onwards. Culture of shellfish (mussels) and marine shrimps (white shrimps) give the highest yields.

Freshwater aquaculture includes culture in ponds, paddy fields, cages and ditches. Most farms are densely located in areas which have abundant water resources or which are irrigated. Production (mostly pond culture) is concentrated in the central plain and coastal zones. The major finfish species in brackish water aquaculture are groupers and barramundi, usually reared in cages and ponds.

The fisheries sector plays an important economic role and generates employment for around 700 000 people, both directly in fisheries enterprises and indirectly in related industries.

Constraints and conflicts have emerged during the intensification of aquaculture in Thailand. Most importantly, depletion of coastal resources and environmental degradation has resulted from discharge of effluent from shrimp ponds into natural water bodies. The receiving waters may suffer from reductions in oxygen levels, hypernutrification leading to eutrophication, increased turbidity and siltation of canals due to suspended solids in the effluent, sometimes leading to alteration in the structure of the benthic community. Contamination of receiving water bodies by chemical and drugs such as antibiotics and pesticides used in aquaculture also occurs.

Conversion of land from agricultural production to shrimp farming represents an economic loss to the agricultural sector. The land lost to agriculture may be greater than the area occupied by the aquaculture operation due to environmental changes induced by shrimp farms. In the early days of aquaculture development in Thailand, mangrove forests were cut to construct shrimp farms, this carried wide implications since most mangrove forests are communally used resources from which products for subsistence and for sale are harvested. The value of these products was calculated to be 14 700 Baht/rai/year. Whilst this amount was substantially below the return from shrimp farming, loss of this resource removed perhaps the only income source for many local residents

As a result of resource conflicts among shrimp farmers, confrontations between shrimp farmers and local farmers and residents have occurred over discharge of effluent water into public waterways and coastal seas, as well as salinity intrusion from shrimp farms to freshwater bodies or agricultural areas. Some farmers in the Inner Gulf of Thailand moved to culture marine shrimp in inner inland areas, using low water salinities and zero discharge techniques. However, saline intrusion of adjacent areas nevertheless caused loss of agricultural potential in affected areas.

Although Thailand has made considerable progress in developing intensive aquaculture systems with minimal social and environmental impacts, the wide variability of production practice and compliance

levels means there are a number of opportunities and priorities for sustainable intensification of the sector. Many of these needs are already covered by legislation, and are a matter of the effectiveness of enforcement. For example, increased efforts are needed to ensure that aquaculture operations are not located within conservation areas, and that operations use environmentally friendly technologies and management practices (including effective waste treatment before discharge, compliance with prohibitions on use of drugs, antibiotics and other chemicals, and sanitation methods that do not impact on the adjacent community). Farms must also record all activities in order to be granted certification.

All these requirements can be addressed through improved effectiveness and enforcement of existing regulations. In particular, regulations issued by the Ministry of Agriculture and Cooperatives including the coastal land use plan of the Department of Land Development need to be strengthened to allow for the designation of zones for aquaculture. Clarification of responsibilities with regard to development of the coastal area is also needed to facilitate enforcement.

Local administrations should become more involved in aquaculture pollution control, and should be given a better understanding of new advances in water quality analysis, feeding technology, and in community facilitation and interaction to resolve resource conflicts. Local administrations and fisheries extension officers will have an increasingly important role to play in technology upgrading and farmer training, since about 78 percent of Thailand's aquaculture farmers are small-scale. There is also an urgent need for strengthening farmer groups and associations.

Thailand's Department of Fisheries (DOF) has given close attention to develop farming systems, management practices and regulations to address issues related to sustainable intensification, and has introduced a number of initiatives. These include the establishment and implementation of minimum national standards (GAP and Code of Conduct) for aquaculture operations, support for production using closed systems, promotion of use of specific pathogen free (SPF) seed, which have been domesticated or selected for good growth or disease resistance. DOF has also addressed feed quality issues by mandating a standard protocol for regulating and monitoring fish and shrimp feed quality. DOF also sets a high standard for quality of discharge water.

16. TIMOR-LESTE: Timor-Leste Experiences in Improving Management of Aquaculture

Domingos Goncalves, Senior Officer, National Directorate of Fisheries and Aquaculture, Ministry of Agriculture and Fisheries, Timor-Leste

With almost half of the population living in extreme poverty and food insecurity, increasing food security is a critical issue in Timor-Leste. Protein is scarce and expensive, and so aquaculture offers a route to providing a balance diet. Historically there is limited aquaculture in Timor-Leste, but the country has over 735 km of coastline, with about 100 coastal communities where 14 percent of the population is engaged in fisheries. With coastal, territorial and EEZ waters of 61.500 km^2, there is a major potential for coastal fisheries and mariculture. Development of these resources could contribute to meeting the demand for fish in coastal communities, whilst utilization of seasonal freshwater resources of 5 008 ha, combined with construction of freshwater ponds could help filling the gap in inland areas. In addition, a number of saline lakes could be utilized for Artemia production.

Suitable freshwater species include freshwater prawn (*Macrobrachium rosenbergii*), catfish (*Clarias macrocephalas*), freshwater eel (*Anguilla sp.*), crawfish (*Cherax spp.*), carp (*C. carpio*), silver and grass carp and tilapia. Brackish water species include black tiger prawn (*P. monodon*) and whiteleg shrimp (*P. vannamei*), milkfish (*Chanos chanos*), mudcrabs (*Scylla serrata*) and oysters (*Crassostrea sp.*). Marine species include octopus (*Pinctada maxima*), grouper (*Epinephelus malabaricus*), snapper (*Lutjanus sp.*), seabass (*L. calcarifer*) and seaweed (*Eucheuma cottonii*).

However, the challenges to development are considerable, from weak infrastructure, insufficient supplies of essential inputs such as quality seed and feed, and limited technical expertise and resources within government agencies. A number of activities have therefore been initiated to promote sustainable aquaculture development in Timor-Leste, including promotion of mariculture in selected areas, mapping the potential for aquaculture development, and development of a National Strategy for Aquaculture Development.

Seaweed cultivation (essentially the farming of Eucheuma cottonii), has proved a successful aquaculture subsector. Beginning in 2003–2004, a group of 20 farmers participated in pilot trials. Based on their success, the number grew steadily and by 2009 there were 1 282 participating farmers. The geographical focus has mainly been on Atauro – a small island situated to the north of Dili with a population of about 10 000. Seaweed culture in Timor-Leste, especially in Atauro has triggered several developments, such as the recent mapping of the country's aquaculture potential and the completion of the National Aquaculture Development Strategy (2012–2030). Both these initiatives were completed in 2011 with assistance from development partners.

In 2012, assistance was provided via the WorldFish Center to build capacity within the Department of Aquaculture and other relevant institutions. This led to recommendations on the policies, regulations and institutional development required for responsible development of aquaculture. An implementation plan was prepared that included two pilot investment projects, one in an inland area and the second in a coastal area, for follow-up action. A stakeholder meeting/workshop was held in Dili in 2012 to present the findings of the study and the draft aquaculture strategy.

The strategy aligns with the Timor-Leste Strategic Development Plan (2011–2030), the Code of Conduct for Responsible Fisheries, and the FAO Technical Guidelines for Responsible Fisheries on the Ecosystem Approach to Aquaculture (EAA).

The National Aquaculture Development Strategy promotes mariculture development according to a number of key principles. States and users should conserve aquatic ecosystems whilst maintaining the

quality, diversity and availability of fishery resources Decisions. Need to be based on the best scientific evidence available, and take into account traditional knowledge. A precautionary approach is essential to protect and rehabilitate critical habitats.

In regard to governance, it is important to ensure transparency and community participation in decision-making processes, and especially to protect the rights of fishers and fishworkers and increase awareness of responsible fisheries through education and training. The government should consider aquaculture, including culture-based fisheries, as a means to promote diversification of income and diet.

17. VIET NAM: Sustainable Intensification of Aquaculture in Viet Nam

Nhu Van Can, Deputy Director, Aquaculture Department, Fisheries Administration, Viet Nam

Aquaculture sector in Viet Nam plays an important economic role. In 2011, total production reached 3.05 million tonnes, equivalent to 58 percent of total fisheries production. Pangasius (38 percent), dominates aquaculture production, followed by traditional fresh water species (28 percent) and shrimp (16 percent). Pangasius and shrimp mainly destined for export, whilst traditional freshwater species serve domestic demand. Aquatic products contribute significantly to food security, providing an estimated 40 percent of animal protein consumption. In 2011, exports reached US$6.18 million, equivalent to approximately 5 percent of GDP.

Traditional freshwater aquaculture production is stable at approximately 850 tonnes per annum, accounting for 28 percent of total aquaculture production for long time and mainly serving the domestic market. Production is mainly through extensive or semi-intensive small-scale systems. However, tilapia production is increasing rapidly.

At present, pangasius is mostly cultured in intensive or super-intensive systems where productivity may exceed 300 tonnes/ha. Whiteleg shrimp is normally farmed intensively, whilst in contrast, tiger shrimp may be farmed under various systems, from extensive, semi-intensive, intensive or even "ecological" and organic culture methods.

Consolidation in the sector is resulting in the rapid emergence of many large integrated farms, covering grow-out, processing and export, and in some cases even seedling production. Nevertheless, despite substantial increases in production in recent years, Viet Nam's potential is not fully realized. A tendency to focus on maximizing production, without concern for food safety or disease prevention, has resulted in disease outbreaks in shrimp, and fluctuations in production (e.g. in pangasius) that caused price instability.

Several other constraints hamper sustainable intensification of aquaculture in the country. First, the large number of small-scale farms complicates sector management, especially in regard to food safety, disease surveillance and environmental integrity. Combined with reluctance to risk adoption of new technologies, or other resources such as credit or new market channels, widespread unsustainable practices, low productivity and frequent disease outbreaks are widespread common among small-scale farms. Use of poor quality of seed, feed and use of chemicals/drugs also contribute to frequent failures in production among smallholders. High quality of seed, feed and other inputs are essential to ensure sustainable intensification at any scale.

The large number of small farms presents the government with a major challenge for master planning, without which it is difficult for government agencies to develop effective environmental monitoring programmes, or to control production volume. Because of ineffective controls over production, price-volume fluctuations and supply-demand crises are sometimes seen, especially in the case of pangasius. Other contributing factors include sharp increases in input costs such as feed, seed and chemicals, and unfair competition among stakeholders in the value chain, and between members at the same stage of production.

Climate change may also bring considerable ongoing challenges to Viet Nam's aquaculture. Coastal areas and the Mekong basin are especially vulnerable to increasingly frequent natural disasters.

In order to proceed towards sustainable intensification of aquaculture in Viet Nam, a number of priorities need to be addressed. First, strengthening of the legislative framework for better sector management should be accelerated at both central and local levels to ensure the quality of inputs and outputs. In this

regard, it will be a priority to establish a robust master plan that incorporates a zoning programme for key cultured species, this will contribute to a measured, controlled and sustainable development of the sector that minimizes competition or conflict with other economic activities. The Master Plan should also incorporate provisions to improve market linkages and equitable sharing of benefits among value chain participants, in order to maintain price-volume stability.

In view of the predominance of small-scale farming and attendant problems (referred to above), more attention should be given to supporting small-scale farms, including support and promotion for adoption of Good Aquaculture Practice, and application of new technologies and services. Development of new and effective technologies and cultured species resilient to climate change will be an important factor in the sector's long-term stability.

The government should actively promote application and certification of aquaculture operators under the national standard for good aquaculture practice (VietGAP), and strengthen the role and accountability of actors within the associated control system, including government (standards, regulation, inspection, promotion); the private sector (third party assessment, evaluation and certification); farmers (application); consumers, processors, and exporters (using the products – compliance with and promotion of standards).

Viet Nam's *Pangasius* industry is presented as a success story of sustainable aquaculture intensification. *Pangasius* is indigenous to Viet Nam, and its culture has seen dramatic growth over the past 12 years, increasing by a factor of 5 from 2001–2011 to 6 000 ha. Over this period, annual commercial production of raw fish increased 36 times, from 37 500 tonnes to 1.35 million tonnes. Productivity in pond culture now exceeds 300 tonnes/ha. Export revenues have increased by 45 times, from US$40 million to US$1.805 billion. Viet Nam now exports to 136 countries.

The success is attributed to the shift from cage to pond culture, synchronized technologies along the entire production chain, promotion of good aquacultural practices and effective market development and export diversification.

Annex 1 Consultation Prospectus and Programme

Regional Consultation on Sustainable Intensification of Aquaculture in Asia and the Pacific 9–11 October 2012, Bangkok, Thailand

Background

The world population is forecast to reach more than 9 billion by 2050. To feed these numbers, global agricultural output including crops, livestock and fisheries must increase by around 60 percent from present levels. Our starting position is that globally nearly one billion people are suffering from hunger now. More than half of them, 578 million, live in the Asian region.

Fisheries products play an important role in food security and nutrition by providing low-cost animal protein, healthy fats and nutrients. Fish is often the only affordable source of animal protein available to poor and nutritionally challenged people, and can exceed 80 percent of dietary protein intake in some countries such as Cambodia. Due to stagnant capture fisheries production, aquaculture development is seen as the only sustainable way to meet the increasing world demand. Around 50 percent of global foodfish supplies already come from farmed sources.

Asian aquaculture has grown rapidly over the past three decades, and now represents more than 90 percent of global aquaculture output by volume. The growth of the industry has largely been a result of two major factors; intensification through technological advances and increased use of feed and other resources. While the growth of Asian aquaculture has contributed to food security and rural livelihoods, it has also caused significant environmental disturbance.

Intensifying aquaculture production in a *sustainable* manner is a massive challenge. Just to maintain per capita fish consumption at current levels will require an increase in global supply of around 60 percent. The target will be even higher for the Asia-Pacific region, when population trends and dietary preferences are taken into consideration. Meeting this demand using conventional farming practices will not be possible without causing irreversible environmental impact.

The utilisation of natural resources in agricultural production is increasingly being understood in terms of the related ecological costs. Maintaining environmental integrity while increasing food production by 60 percent will require that all agricultural sectors reduce their unit production environmental footprint. Many farming practices that are regarded as sustainable today will simply not be sustainable when conducted on a larger scale. Competition for essential resources such as water, suitable farming sites, energy, fishmeal, fish oil and other feed ingredients will inevitably constrain the growth of the industry.

Sustainable intensification of aquaculture means *doing more with less*. Aquaculture must become a more efficient user of natural resources, both in terms of farm productivity and environmental efficiency. Each kilogramme of food grown tomorrow must have less environmental impact than it does today. We need to start building more efficient farming systems now and for tomorrow. As the leading aquaculture region with more than 90 percent of world production, this challenge presents both opportunities and responsibilities for the Asia-Pacific region.

Focus

The objective of the consultation is to *develop a regional strategic framework to guide national governments and regional organizations in promoting sustainable intensification of aquaculture in the Asia-Pacific region*. The consultation will also identify priority actions for the region and, where possible, practical measures for their implementation.

The consultation will specifically focus on intensifying aquaculture through *more efficient use of resources and environmentally sound practices*. Farm productivity and environmental performance must be improved through a combination of forward-looking policies, better management practices and technological improvements, rather than by increasing inputs to the system.

The participants will share their experiences and lessons from the past performance of aquaculture development, identify issues and constraints for improvement, and share success stories and capture promising new directions that will guide Asian aquaculture towards more sustainable practices.

The consultation will consider the above issues within the prevailing socio-economic context of aquaculture in the Asia-Pacific region – a sector characterised by large numbers of small-scale, family-operated farms that require special attention if aquaculture is to continue to contribute significantly towards their improved livelihood. Practical interventions must address this reality if real change is to occur.

Organization

The consultation is sponsored by FAO and jointly organized and convened by FAO, the Asia-Pacific Fishery Commission (APFIC) and the Network of Aquaculture Centres in Asia-Pacific (NACA).

Participation

Twenty-three countries in Asia and the Pacific Region, most of which are members of APFIC and NACA will be invited to the consultation. The consultation will bring together representatives from national governments, regional and international bodies, development partners, and selected leading regional and international actors from the public and private sectors in a roundtable consultation.

Process

The consultation will seek to share experiences and lessons learned in an interactive series of working group sessions examining key issues and constraints to sustainable intensification of aquaculture; priority actions that must be taken, and practical policies and implementation mechanisms to drive real change. It is hoped that the discussions will culminate in the development of a regional strategic framework to aid governments and development agencies in facilitating the sustainable intensification of aquaculture in the region.

Outcome

The expected outcome of the regional consultation will be extensive sharing of existing knowledge, experiences and lessons learnt on sustainable intensification of aquaculture among the member countries, international and regional organizations and other stakeholders and development of a regional strategic framework and plan of action to support the sustainable intensification of aquaculture in the Asia-Pacific region.

Outputs

The regional consultation is expected to produce the following outputs:

- Enhanced knowledge and understanding on sustainable intensification of aquaculture among the member countries, regional organizations and other stakeholders in the Asia-Pacific region;
- Enhanced networking and partnership among the different stakeholders in promoting sustainable intensification in the region;
- Short and medium term regional strategic framework supporting sustainable intensification of aquaculture in the region and regional action plan, which could be taken up and endorsed by the regional priority setting bodies (such as APRC, APFIC and NACA etc.);
- A full consultation report including expert review papers, successful stories and country position papers on the sustainable intensification of aquaculture in the region; summaries of the meeting discussions and as well as the regional strategic framework and the action plan;
- A technical publication on "Sustainable Intensification of Aquaculture in Asia and the Pacific" extracted from the consultation report.

Programme

Day 1	**Arrival of participants**
Day 2	**Challenges, Technologies and Tools**
08.00–09.00	Registration and assembly
09.00–09.30	**Opening session: Welcome/opening remarks by:** • Director General, NACA • Director General, Department of Fisheries, Thailand • Assistant Director General, FAO-RAP
09.30–10.00	**Keynote address:** Global perspective of status and future trend of supply and demand, vision of global aquaculture development and the implication for sustainable intensification in Asia-Pacific
10.00–10.30	*Group photo and coffee break*
10.30–11.00	Feeding 9 billion people sustainably: Challenges for Asian aquaculture
11.00–11.30	Marine capture fisheries as a source of feed for aquaculture in the Asia region
11.30–12.00	Comparative analysis on sustainability and resource use efficiency of major aquaculture systems and commodities in Asia-Pacific
12.00–12.30	Implication of social and economic changes (urbanization, marketing, gender and rural livelihoods) on sustainable intensification of aquaculture in Asia-Pacific
12.30–13.30	*Lunch break*
13.30–14.00	Genetic improvement – the role of selective breeding, access to genetic resources and benefit sharing in sustainable intensification
14.00–14.30	Improved feeds and feeding strategies – reducing the economic and ecological costs of feeds by improving feed use efficiency
14.30–15.00	Balancing natural resource use and the environmental costs of aquaculture
15.00–17.30	**Working Group Session I: Priority issues and options for sustainable intensification of aquaculture in Asia-Pacific** Participants will identify key issues, constraints and opportunities in the sustainable intensification of aquaculture, focussing on key Asian aquaculture commodities/ systems in detail. *Coffee will be available at liberty throughout this session*
Day 3	**Regional Strategic Framework and Plan of Action**
09.00–09.30	Trade, markets and value chain management for the sustainable intensification of Asian aquaculture
09.30–10.00	Application of aquaculture planning and management tools for sustainable intensification of aquaculture
10.00–10.30	Better management practices and sustainability: Experiences with shrimp, catfish and culture-based fisheries; and cluster approaches to improve small-scale farming practices
10.30–11.00	*Coffee break*

11.00–11.30	Promising aquaculture practices for sustainable intensification
11.30–12.00	Sustainable ethical aquaculture trade
12.00–12.30	Role of private sector corporations (market chains and supporting industries) in sustainable aquaculture
12.30–13.30	*Lunch break*
13.30–14.00	Sustainable intensification – farmer group perspective
14.00–17.00	**Working Group Session II: Development of a regional strategic framework and action plan to support sustainable intensification of aquaculture in Asia-Pacific** • Participants will develop a regional strategic framework and action plan to support the sustainable intensification of aquaculture in the short-term (2 years) and mid-term (3-5 years). The framework will address policy recommendations, implementation strategies, priority actions and resource mobilization strategies. The discussion will focus on the key issues identified in Working Group Session I. • Rapporteurs synthesise the recommendations into a strategic framework for presentation in the morning session *Coffee will be available at liberty throughout this session*
Day 4	**Sharing of country experiences and success stories and development of strategies and action plan promoting Sustainable Intensification of Aquaculture at national level**
08.30–10.30	Sharing of experiences/success stories in sustainable intensification of aquaculture from selected Asian aquaculture producing nations • Presentations from 6-8 selected countries • Plenary open discussion
10.30–11.00	*Coffee break*
11.00–12.30	**Working Group Session III: Development of strategies and action plans for promoting the sustainable intensification of aquaculture at the national level** • Participants will discuss strategies and plans to facilitate sustainable intensification of aquaculture at the national level
12.30–13.30	*Lunch break*
13.30–15.30	**Plenary discussion: plenary discussion and adoption of regional strategic framework and action plan supporting Sustainable Intensification of Aquaculture consolidated from working group session II outputs.** • Presentation of the draft strategic framework consolidated from working group discussions for consideration by the consultation • Plenary open discussion and comments on the framework • Discussion of follow up activities, resource mobilisation strategies and ongoing networking on sustainable intensification of aquaculture • Seek commitment of participating countries in formulating national strategies and action plans for sustainable intensification of aquaculture
15.30–16.00	*Coffee break*
16.00–16.30	Closing session

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ISBN 978-92-5-108586-8

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I4094E/1/09.14