FWG 01/99 – Collaborative APEC Grouper Research and Development Network

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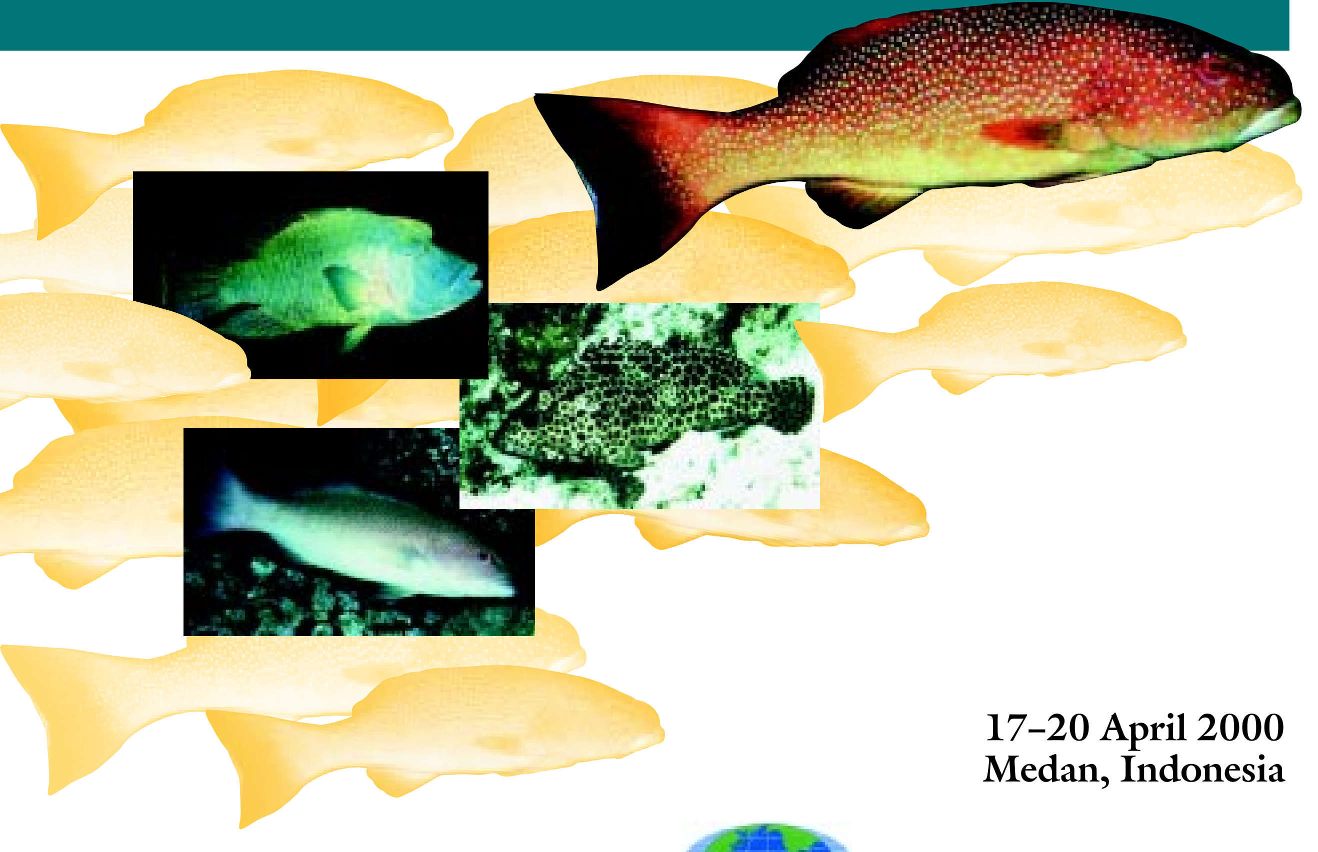
Regional Workshop on Sustainable Seafarming and Grouper Aquaculture



17–20 April 2000
Medan, Indonesia

Organised by the
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in cooperation with the

Government of Indonesia

Network of Aquaculture Centres in Asia-Pacific (NACA)

Bay of Bengal Programme (BOBP/FAO)

Collaborative APEC Grouper Research and Development Network (FWG 01/99)

Report of the Regional Workshop on Sustainable Seafarming and Grouper Aquaculture

Medan, Indonesia
17-20 April 2000

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Workshop Proceedings

Introduction

Workshop Background

The workshop was organised by the Asia-Pacific Economic Cooperation (APEC) and hosted by the Government of Indonesia in cooperation with the Bay of Bengal Programme (BOBP-FAO), and the Network of Aquaculture Centres in Asia-Pacific (NACA). The workshop is one of the activities under the APEC-NACA "Collaborative Grouper Research and Development Network".

The Workshop involved 55 participants from APEC economies throughout the Asia-Pacific, including: Australia; Hong Kong, China; Indonesia; Japan; Malaysia; Philippines; Singapore; Thailand and Vietnam. Representatives attended the meeting from NACA, the Secretariat for the Pacific Community (SPC), the Solomon Islands, Myanmar, INFOFISH, and a non-governmental organisation, The Nature Conservancy (TNC). Delegates from China, India and Korea were unable to attend this workshop, however, all indicated a keen interest in the proceedings and recommendations arising from the Workshop and their willingness to participate in grouper network activities and project development.

The list of participants is attached as Annex 1. The programme is attached as Annex 2. The workshop was the second under the APEC Fisheries Working Group (FWG) project FWG 01/99 "Collaborative APEC Grouper Research and Development Network". The workshop focussed on grouper culture, but also explored management strategies required to support the sustainable development of seafarming in the Asian region. The emphasis was on technology transfer and management strategies for the benefit of farmers and coastal communities. The workshop included special sessions on diversification of seafarming systems and culture species, the role of seafarming in the livelihoods of coastal communities and an update on recent progress and options for further development and expansion of the APEC-NACA "Collaborative Grouper Research and Development Network".

The workshop emphasized practical management and development strategies including the evaluation of the potential of sustainable hatchery and farming enterprises for groupers and other marine finfish species to contribute to income generation, poverty alleviation and food security throughout the region.

The workshop was held in Medan, Indonesia on the 18-20 April 2000 with an opening ceremony held on the evening of 17 April 2000. It was also held in cooperation with the Bay of Bengal Programme, which sponsored some of the participants from the Bay of Bengal region, and from within Indonesia.

The meeting was very successful, with a number of key recommendations being made in support of APEC FWG and NACA objectives for grouper aquaculture. Specifically, the Workshop recommended further expansion of activities to cover coastal livelihoods, improved environmental management of cage aquaculture, and most importantly the formalisation of the participation of the centers and institutions involved in the network.

Workshop Objectives

The objectives of the workshop were:

1. Awareness-building on sustainable management practices for seafarming
2. Identification of current needs and actions required for promoting sustainable seafarming in Indonesia and within the Asia-Pacific region
3. To review and identify strategies for ensuring that research on grouper aquaculture and seafarming leads to improved livelihoods of rural coastal communities
4. To evaluate the potential for development of sustainable localised hatchery production of marine finfish to support aquaculture development, and
5. To identify appropriate follow up activities from the workshop within Indonesia and in other countries of the region through collaborative research, training, extension, demonstration projects and other relevant activities

Workshop Programme

Opening Ceremony

The workshop started with an opening ceremony on the evening of 17 April 2000 with welcoming speeches made by the Governor of North Sumatra, the NACA Coordinator (Hassanai Kongkeo) and Kee Chai Chong (BOBP Project Coordinator). Mr Untung Wahyono (Director-General, Directorate General of Fisheries) gave the keynote address. In his address, Mr Untung emphasised the importance of sustainable development of seafarming and the need for technological development and a legal framework. Following this keynote address, Mr Untung declared the workshop open.

Session I: Technical Session

The following presentations were made during the first technical session:

- Overview of the workshop and objectives by Sugiri Elon, Director of Production, Directorate General of Fisheries, Indonesia
- Present status and strategy of Indonesian mariculture development by Tati Ramelan, Director of Seed Production, Directorate General of Fisheries, Indonesia
- Regional overview of marine finfish farming, with an emphasis on groupers and regional cooperation by Hassanai Kongkeo, NACA
- Overview of Asia-Pacific Grouper Network (APGN) strategic research plan and ACIAR grouper project update by Mike Rimmer, Queensland Department of Primary Industries, Australia
- Status of breeding and larval rearing of grouper by Joebert Toledo, SEAFDEC AQD, Philippines
- Breeding and larval rearing of barramundi cod (*Cromileptes altivelis*) in captivity by Ketut Sugama, Gondol Research Institute for Mariculture, Indonesia.

- Review of grouper diseases and health management strategies for grouper and other marine finfish diseases by Somkiat Khanchanakhan, Aquatic Animal Health Research Institute (AAHRI), Thailand and Melba Reantaso, NACA
- Feed and feed management practices by Renee Chou, Agri-food & Veterinary Authority of Singapore, Singapore
- The availability and use of local ingredients in fish feed for humpback grouper grow-out by Taufik Ahmad, Research Institute for Coastal Fisheries, Indonesia
- Environmental management of mariculture: the effect of feed types on feed waste by Jim Chu, Agriculture and Fisheries Department, Hong Kong, China
- Grouper aquaculture in Myanmar by U Win Tin, Department of Fisheries, Myanmar
- Grouper aquaculture in the Philippines by Westley Rosario, BFAR-NIFTDC, Philippines
- Grouper aquaculture in Malaysia by K. Subramaniam, Department of Fisheries, Malaysia

The next part of this technical session included the following presentations on alternative seafarming species and systems.

- Development of new artisanal fisheries based on the capture and culture of postlarval coral reef fish by Cathy Hair, ICLARM, Solomon Islands
- Hatchery development options for marine fish by Peter Lauesen, SINTEF Fisheries and Aquaculture, Norway
- Perspective on future directions in cage culture related to Asia by Niels Svennevig, SINTEF Fisheries and Aquaculture, Norway

Session II: Special Session on the Social and Economic Aspects of Marine Fish Culture and Coastal Livelihoods

The following presentations were made during this special session:

- Towards sustainable harvesting of live reef food fish species in the Solomon Islands by Michelle Lam, Ministry of Agriculture & Fisheries, Solomon Islands
- Preliminary report on the regional survey of fry and fingerling supply and current practices for grouper mariculture by Yvonne Sadovy, The University of Hong Kong, Hong Kong, China
- An overview of the Komodo fish culture project by Peter Mous, The Nature Conservancy, Indonesia
- Seafarming and community development in the Philippines by Renato Agbayani, SEAFDEC AQD, Philippines
- Managing aquaculture sustainability using input-output relationships by Kee Chai Chong, BOBP, India
- Markets for cultured grouper and other marine finfish by Sudari, INFOFISH, Malaysia
- Assessing the sustainability of small-scale grouper culture in Southern Thailand by Natasja Sheriff, Asian Institute of Technology, Thailand

Session III: Review of Research Program and Prioritisation for Future Research (followed by discussion session)

The session opened with a presentation by Mike Rimmer, Hassanai Kongkeo, and Michael Phillips that provided a review of the regional research program on grouper. Following the presentation, the workshop divided into three working groups. The groups addressed the following major issues raised during the preceding technical and socio-economic sessions, with an emphasis on practical follow-up actions: research needs, demonstration projects, staff exchanges, responsibilities of different centers and institutes, and regional networking. The Terms of Reference of the Working Groups are given as Annex 3.

Report of the Working Groups

Working Group 1: Coastal Livelihoods and Socio-economic Issues

Chairperson: Lars Engvall
Rapporteurs: Renato Agbayani and Natasja Sheriff

Management Approach to Seafarming Based on Objective of Improving Coastal Livelihoods through Seafarming Development

The discussion focused on the management approach and other factors that need to be considered before seafarming can be promoted in coastal communities. The point was raised that the goals behind seafarming development should be more specifically defined (the development of coastal communities, use of marine protected areas, environmental rehabilitation). This arose from the consideration that seafarming might provide an alternative to destructive fishing practices. Seafarming was suggested as a way that could support coastal management and provide an alternative to unsustainable fishing practices. Attention should be focused on implementing recommendations of past research and the introduction of the results to communities. However, an understanding of the needs of coastal communities and the ability of mariculture to meet those needs is required.

It was agreed that seafarming is a possible option for improving coastal livelihoods, but a number of factors should be taken into consideration prior to development:

- *Markets*
  Availability of marketing channels. Does a market exist and is it easily accessible by the community? Communities need access to information on markets.
- *Environmental problems and zoning*
  Consideration should be given to zoning areas used for seafarming. Other considerations are the intensity of culture, carrying capacity, governing legislation, enforcement and regulation.
- *Identify channels of information dissemination and awareness building*
  It was suggested that many communities have little awareness of seafarming or the possibility of participation in seafarming activities. Methods of transferring

information and entry points should be identified. Participatory approaches to development should be promoted.

- *Property rights and ownership*
  Particular emphasis was placed on the success of resource management and community enforcement when the community owned the resource that they used and protected. This requires some degree of organisation and cooperation in the community. The community may not invest in the resource if it does not belong to them.

- *Risk minimisation and analysis*
  The identification of risk is important if people are going to invest resources in a new venture. Consideration needs to be given to the minimisation of risks and possible subsidisation from a cooperative, for example, to absorb some of these risks resulting from impacts of disease or market fluctuations. A cooperative is a management option that may lead to the minimisation of risk.

- *Understanding the development context*
  A key issue was the need to consider the promotion of mariculture within an appropriate development context. There is a need to look at the whole picture, including the impacts of the introduction of seafarming into coastal communities.

Review of the Recommendations of the Socio-economic Group Discussion from the Hat Yai APEC-NACA Workshop and Specific Suggestions on their Development and Implementation

The Hat Yai working group proposed a training and extension program for aquaculture, including:

- The development of a grouper health management manual for farmers involved in grouper production which builds on existing surveys being undertaken through existing APEC projects. It was recommended that this project receive high priority (note: this project was implemented in 2001).
- The development of education and extension programs for farmers living in regional areas. Methods to implement this would include ACIAR project meetings, APEC workshops within APEC-NACA projects and other regional training programs.
- Best practices for grouper aquaculture.

It was suggested at the Medan meeting that conditions are not yet ready for training, extension and development. Development of these projects would signify an end point when information would be disseminated, and when the context and implications of development are clearer.

The Hat-Yai working group emphasized the following points:

i) Networking in grouper aquaculture should be extended to other species
ii) There were a number of other marine fish species (including non-carnivorous species) which offer developmental potential
iii) Many coastal farmers involved in grouper aquaculture also farmed other species, and switched species depending on market conditions
iv) The potential of aquaculture to alleviate illegal fishing would probably depend on offering options to coastal farmers, of which grouper aquaculture would be one, and

v) There were a number of coastal livelihood and environmental rehabilitation projects in the region. Such projects should be integrated into the network to allow research on technologies to be transferred to a development context.

Point (iv) was discussed at length. It was suggested that strong incentives are required for fishers to give up destructive practices in favour of aquaculture. Many fishers are caught in a debt trap and unable to choose a new livelihood option. It was emphasized that it is not a straightforward task to introduce a new technology; the current context of activities and the potential and ability to change must also be understood. The need is to remove fishers from their current situation before they are able to opt for an alternative.

The term 'illegal' in the context of fishing was clarified to mean destructive fishing practices, as opposed to operating without a licence.

The Hat Yai group proposed that a broad assessment should be conducted on the potential for marine fish farming in the Asia-Pacific region, developing a regional cooperative strategy to meet development opportunities. Activities suggested included:

i) Marketing and product diversification analysis
ii) Fish species analysis and identification of potential development
iii) Case studies to facilitate development of strategy and policy for marine fish culture and business development, including coastal livelihoods and environmental rehabilitation projects
iv) Prepare development scenarios for major cultured species and constraints and opportunities for development of small and medium scale business, and
v) Identify opportunities for cooperative networking to meet development opportunities and overcome constraints

The Medan working group prioritised activities i), ii), and v) for future development.

Evaluate the Potential for Development of Sustainable Hatchery Production to Support Aquaculture Development

Indonesian representatives presented problems they encountered in technological transfer. It was suggested that cultural differences may influence project success as hatchery projects had been implemented successfully in Bali, but not in Sulawesi. Problems were encountered in the maintenance of broodstock and egg transportation. It was suggested that small-scale nurseries were a better option for small-scale coastal fishers and farmers, than hatcheries. However, it was necessary for nurseries to have access to eggs and fry from hatcheries, which were most likely to be large-scale.

The possibility of attracting investors to hatchery developments was discussed. Incentives might be required, such as training. Also, the assessment of risks and their minimisation may be required.

It was concluded that in the medium term (5-10 years), hatchery development should be implemented at a centralized location, but 'backyard' nurseries should be promoted. It was concluded that attracting investors should be given attention.

Development of Specific Follow-up Recommendations for Management of Seafarming for Improving Coastal Livelihoods

The recommendations were based on the discussions above. The Terms of Reference suggested that projects should be included in the recommendations where necessary.

These could be targeted at follow-up in Indonesia, BOBP countries, and more broadly within APEC economies and the Asia-Pacific region. Collaborative research, training, extension, demonstration projects, identification of possible exchange opportunities, discussion and recommendations on possible strategy to exchange experience on small pilot projects were given attention.

Use of Case Studies

The use of case studies was identified as a priority activity. Specific areas of interest that could be assessed using case studies were identified. A number of issues were discussed:

- Before seafarming is proposed, the socio-economic context and opportunities and constraints for development should be understood. Case studies are one way to achieve this. An understanding of risk minimisation strategies could also be gained through case study work
- Case studies should permit the identification of specific recommendations for areas in which seafarming is feasible and cases where it is not
- Sites to be used for case study work should not necessarily be selected geographically. The cases should describe suitable locations for study matched to research requirements
- Case studies should distinguish between areas in which culture has been taking place for a number of years, and those in which there is limited experience of mariculture or no culture experience
- The Solomon Islands could be an interesting region for research. It was suggested that it might be two years before fish culture will be developed, but clam culture was introduced a number of years ago. It may be of interest to look at the contribution of seafarming to livelihoods in this region. It will also be beneficial to incorporate Pacific communities into current research activities. ICLARM is currently trying to transfer hatchery technology to local producers.

The following areas for case study development were proposed:

i) Evaluation of areas in which seafarming is established
ii) Evaluation of failed projects to understand reasons for failure, and
iii) Socio-economic opportunities and constraints to mariculture development

There was some discussion as to whether specific issues should be addressed or whether an understanding of the wider picture (situation appraisal) was more appropriate. There was disagreement regarding the validity of considering issues in isolation. The institutional context was considered to be important, but the discussions demonstrated how difficult it is to separate the issues. Acquiring too much detail of specific issues may lose validity at regional level, and may only be relevant in one location. It was agreed that an assessment of existing institutional arrangements might at least show lessons learned and possible opportunities for application elsewhere. Case studies can show project specific issues while providing more general information and lessons learned. Each case study would not have to cover all issues. There were difficulties in reaching agreement on this topic. It was therefore decided to leave the discussion and focus on case studies as identified above.

Staff Exchanges

Possibilities for staff exchanges in projects that are already implementing seafarming projects were discussed. Training modules were suggested which might cover issues such as the implementation of aquaculture in coastal communities. The following projects identified a need for exchange and information.

- The Komodo Project requires someone with experience in socio-economics (aquaculture development) to assist with the description of the socio-economic context on Komodo.
- The Co-Fish Project (Indonesia) has been operating for two years. It focuses on community fisheries management with some consideration given to aquaculture. There may be a need for the staff to visit other regions and projects.

In approximately two years, if fish culture develops, there may be a need for staff and information exchanges involving the Solomon Islands.

Training Programs

It was recommended that a workshop be held to discuss appropriate methodologies for information collection, with particular reference to the case studies.

Demonstration Projects

It was suggested that these could be identified through case study work.

Specific Opportunities for Involving the Private Sector

Indonesian representatives reported that a few large companies control seaweed culture. It is now virtually impossible for small farmers to have access to seaweed culture. In the case of pearl farming, farmers have the resources to culture and the Co-Fish Project is trying to get a better deal for farmers through a private company.

Private companies may have a role in culture; supplying the small farmer with fingerlings or marketing. Discussions continued to identify mechanisms by which the private sector could be included in grouper culture and other coral reef fish. Inclusion of the private sector in Komodo was not pursued, as it was difficult to find a private company willing to take the risk. The national park administration and The Nature Conservancy wanted to control the activities of the company to prevent it from becoming involved in fishing activities. The project is looking into contingency loans to alleviate risk, but the project managers do not think that the inclusion of the private sector will be a viable option for Komodo. The Komodo project is also trying to develop a certification program.

There are opportunities and needs to include the private sector in hatcheries but no specific cases to recommend. There is a need for a large-scale umbrella organisation (like a cooperative) to cover small-scale farmers.

Summary of Discussions and Recommendations

Issues when Proposing Fish Mariculture as an Alternative Livelihood

- Markets
- Holistic approach based on understanding of people's livelihoods

- Awareness building
- Risk analysis and minimisation
- Property rights and institutional framework, and
- Environmental concerns and carrying capacity

Hat Yai Recommendations

The Working Group recommended that priority be given to case studies, development studies and identification of opportunities for cooperative networking.

Potential for Localized Hatchery Development

- The Working Group concluded that this is not feasible in the medium term (5-10 years) primarily due to constraints in broodstock development, complicated technology and investment risks, and
- It was agreed that it would be more appropriate to develop central and regional hatcheries integrated with local nurseries

Recommendations on case studies

- The working Group proposed that a series of case studies be implemented
- Three categories were identified

  i) Studies of non-successful seafarming projects
  ii) Evaluation of established mariculture practices, and
  iii) Socio-economic evaluation with opportunities, constraints and risks identified

Training Recommendations

- A workshop to discuss appropriate methodologies, and
- Training or workshops in methodological approaches with particular reference to the needs of case study research

Technical Exchanges

The following exchange visits should take place:

- The Komodo project has identified a need for expertise in socio-economic mechanisms affecting the development of fish culture as a tool for marine protected area management
- The Co-Fish Project has a need to learn more about seafarming in coastal communities, and
- Further opportunities for information and staff exchange will be identified

Involvement of the Corporate Sector

- There are opportunities and needs in incorporating the corporate sector, such as hatcheries, processors and marketing companies involved in seafarming, and
- Opportunities need to be further assessed before specific recommendations are made

Implementation

- A small expert group should be established to follow up the Medan meeting, and develop more specifically the recommendations and follow-up projects and related actions. The group will work mostly by e-mail

Working Group 2: Markets and Certification Issues

Chairperson: Yvonne Sadovy
Rapporteurs: Michelle Lam and Sih Yang Sim

Major Issues Discussed

This working group addressed market, trade and certification issues in grouper aquaculture. The following specific issues were addressed:

- Identification of specific project ideas to deal with key issues
- A review of the recommendations of the markets and trade group discussion from the Hat Yai APEC-NACA meeting, and
- Development of specific recommendations for management of grouper culture through collaborative research, training, extension, demonstration projects and other relevant activities

Key Issues to be Addressed

1. Market incentives (from importing countries) should help ensure compliance with certification schemes; these could include approved restaurants or traders who pledge to deal in certified fishes.
2. Certification should be on voluntary basis at farmer level (mandated certification might be onerous to the small-scale farmer). Incentives to comply with certification schemes should be developed.
3. Live food fish should be classified as 'food'. Live fish is not officially considered 'food' in the major importing economy of Hong Kong, China; therefore, regulations and legislation applicable to food fish may not apply. An example of this is 'ciguatera'. There is no official requirement for live fish to be tested for ciguatoxins (dead fish are tested) thus permitting entry to contaminated fish. Hundreds of cases of ciguatera have been reported in the last few years, undermining public confidence in fish and giving the live reef fish trade a bad reputation
4. Improve recording of landings of live fish: the documentation of the quantities or species of live fish being landed and traded is generally very poor, making it difficult to track declines or problems by species or location. Greater effort and organisation is needed to address this problem since current volumes are grossly underreported. Certain major exporters do not record these fish at all. The Harmonized Code system could be used to document not only fishes destined directly for consumption, but also the juveniles that are traded for culture. In the latter case, there is virtually no documentation at all. The trade cannot be understood or regulated without a system of documentation in place.
5. Monitoring systems of regional trade would help to determine sources of ciguatoxic fishes and to promote trade by countries that comply to certifications and pledge to control damaging collection techniques, such as cyanide. It introduces a degree of accountability into regional trade.
6. Government level training and follow-up would provide additional incentives for grouper mariculture to follow certification. Education is required at all levels to ensure compliance with certification systems
7. A third party and/or government to ensure compliance should provide accreditation at retail level.

8. Middleman awareness and licensing systems are required. It is critical that the middlemen are involved in the development and implementation of any certification or licensing system.
9. End-user awareness education for preferred product; accreditation gives incentive to produce and should get a higher price. Consumers need to be aware of the options and problems such as ciguatoxic fishes from wild capture compared to the safer option of cultured fish.
10. NGOs may have a role in encouraging and forming eco-labeling. This is becoming increasingly important as we come to recognize that some of the fishes in the live reef fish trade are rare or particularly vulnerable. In the future, it may be advisable to distinguish between wild-caught and cultured sources of such fish to encourage taking pressure off wild populations.
11. Standardization of methods, equipment and products (HACCP and ISO) for international trade and consumer confidence in live fish, APEC could work to ensure regional standardization in the adoption and application of codes and standards.
12. Reiterate adoption of eco-labeling [environmentally friendly and cyanide free] Philippines model (certification of hatchery reared or wild caught fry).
13. Implement the FAO Code of Conduct for Responsible Fisheries (CCRF) and develop Codes of Practice. Further work is required on implementation of the CCRF, which should be voluntary in the beginning but eventually mandatory. Develop and adapt Codes of Practice for culturists.
14. Certification of hatchery reared or wild caught fry. This is likely to become important in cases of culturing vulnerable species or in attempting to avoid over-fishing.
15. Truth in labeling, nomenclature and definitions.

Follow-up Recommendations

Based on the various issues raised during the discussions, the Working Group developed the following recommendations.

1. Survey of perceptions at restaurant and consumer level on certification and accreditation (include middleman).
2. Promote compatibility across the region on Harmonized Code Categorization especially on groupers and increase extent and accuracy of monitoring wild-caught fish, including those captured for mariculture grow-out.
3. Chain of command from products to consumers. Contact the Directorate General of the EU to find out requirements and guidelines of live fish in EU market.
4. Market projections and analysis of scenarios with and without certifications or health protection for the public who cannot distinguish safe from unsafe fish.
5. Define the role of APEC in the implementation of the above strategies, especially for certification and adoption of FAO Code for Responsible Fisheries.

Working Group 3: Technology and Management

This working group addressed the technology and management aspects of coastal seafarming development, including grouper aquaculture. Environmental issues were given special attention. The specific terms of reference are given in Annex 3.

General Management Approaches to Seafarming

- *Promote the development of hatcheries to overcome the current fingerling shortage*
  It was noted that viral disease problems, particularly the occurrence of viral nervous necrosis (VNN), is a major constraint to the development of sustainable hatchery techniques for groupers and some other species, such as seabass.

- *Support the development of healthy broodstock populations*
  The discussion raised two points on the development of healthy broodstock:

  1. There is a need to develop more accurate VNN diagnosis methods. Using current polymerase chain reaction (PCR) techniques, individual broodfish will test positive on some occasions and negative on other occasions. This appears to be related to the sensitivity of existing testing techniques, which cannot effectively detect very low infection rates of VNN.
  2. The objective of this component would be to develop specific-pathogen-free (SPF) fingerlings.

- *Improve hatchery technology for fingerling production*
  There is a need for a consistent supply of high quality, healthy fry.

- *Develop specialised feeds for marine finfish*
  1. Storage is a problem in many parts of Asia
  2. Grouper need a floating pellet with high protein
  3. Improved starter and juvenile feeds are required
  4. More cost-effective feeds using local ingredients are needed, and
  5. Machinery for making high protein, high lipid pellets is not available in Asia

- *Improve management of resource conflicts associated with seafarming*
  1. Develop a site selection guide
  2. Adopt FAO Code of Conduct for Responsible Fisheries, and
  3. Improve mariculture management through zoning and licensing

Review of the Hat Yai Workplan

- *Virus project*
  APEC has funded the preliminary stage of this project. Eight countries are involved in the project development phase. An initial meeting will be held in Bangkok.

- *Larviculture R&D*
  The working group discussion reflected the views expressed in the previous workshop that the existing R&D effort (institutional projects linked through the Asia-Pacific Grouper Network, and focused collaborative efforts such as the ACIAR Grouper Aquaculture Project) was adequate. Collaboration between institutional projects should be promoted through staff exchanges under the existing APEC Collaborative Grouper R&D Network project. It is therefore recommended that staff involved in grouper larviculture R&D be encouraged to apply for these staff exchanges, and that these exchanges be supported by APEC.

- *Egg quality assessment*
  Peter Lauesen (SINTEF, Norway) will coordinate this project. Initially, information on assessment techniques will be distributed through the network.

- *Staff exchanges*
  There needs to be wider distribution of staff exchange applications. Some participants were not aware of the availability of staff exchanges under the APEC Collaborative R&D Network project.

- *Environmental impacts*
  The working group recommended that NACA implement and coordinate this project in cooperation with participating institutions. The initial activity would be the collection and review of existing information, as per the project proposal. It was further recommended that NACA incorporate these activities in the next 5-year workplan (2001–2006). In further discussions during the plenary, it was agreed to form a small expert group to communicate via e-mail and develop this important regional activity; first to review existing information; and second to develop a project to undertake the required activities. The expert group should also consider the recommendations on implementation of the FAO Code of Conduct.

Potential for Development of Sustainable Local Hatchery Production

- *There is a need to further improve hatchery production technology*
  The working group participants agreed on the need to develop sustainable local hatchery production and that hatchery production technology needs to improve before uptake can be expected.

- *Develop central broodstock and egg production facilities to supply local hatcheries*
  The working group noted that broodstock maintenance is very expensive and beyond the resources of small-scale farmers. It was proposed that the best model for development of sustainable marine finfish aquaculture is to develop central broodstock facilities that would supply eggs or larvae to local hatcheries. These facilities would probably be government-operated.

- *Additional education and training to potential finfish farmers*
  The working group recognised the importance of additional education and training for farmers prior to adopting the technology to assure the successful application of research results.

Diversification and Technology Transfer

- *Identify potential species suitable for diversification*
  It was recommend that NACA undertake regular market surveys to provide information on potentially profitable species suitable for diversification. It is necessary to gather broodstock of new species well ahead of the time in order to acclimate and domesticate them for hatchery production.

- *Develop multi-species hatcheries*
  The working group recommended multi-species hatcheries development in order to cut the host specific pathogens cycle and assure the successful production of market oriented species.

- *Support development of demonstration projects*
  Workshop participants noted that it was important to sustain existing demonstration projects that could be used for multiple species and commodities, efore commencing new projects.

Provide Training and Technology Transfer

There was general support for increasing intensification of hatchery technology, and it was proposed that marine finfish farmers in Asia could profitably adopt some aspects of technology from Europe.

Specific Recommendations

- *Continue APEC Collaborative Grouper R&D Network activities including:*
  1. staff exchanges
  2. regular workshops
  3. research program coordination
  4. information exchange processes

- *Develop regional Aquaculture Centres and Demonstration Hatcheries*
  It was recommend that NACA coordinate and implement this development as per their existing program for developing regional aquaculture centres.

- *Environmental management*
  NACA should undertake the collection and review of existing information, as per the recommendation above. In addition, there is a need to develop general guidelines for site selection for marine finfish cage farming.

- *Improved growth and production*
  There was consensus that although there are opportunities to improve growth and production of marine finfish species, these should be undertaken in an environmentally and socially responsible fashion. Accordingly, the working group **supported** the development of 'natural' genetic selection programs to support improved growth and production. However, the working group **did not support** the development of genetically-modified organisms (GMOs) or the use of hormones and other growth-promoting chemicals.

- *Promote the development of:*
  1. small-scale nurseries, and
  2. small-scale (backyard) hatcheries, particularly multi-species hatcheries

Private Sector Involvement

- *There are opportunities for private sector companies to develop specific products:* particularly, vaccines, chemotherapeutants and feed (particularly juvenile fish and starter diets).

  It was noted that one company has developed a vaccine for nodavirus that is currently being tested. It was further noted that R&D agencies are primarily involved in production evaluation of commercial products.

Final Session

The final session chaired by Kee Chai Chong derived the following recommendations:

- The importance of continued promotion of networking in groupers, and more generally seafarming development within the Asia-Pacific region.
- The implementation of the recommendations arising from the workshop through regional cooperation.

- Giving strong emphasis to further exchanges of personnel to strengthen research and development activities under the network.
- Formalisation of the networking arrangements through designation of selected institutes as centres within the regional research and development network. NACA and APEC were requested to give this issue special attention.
- The importance of strengthening cooperation in regional grouper aquaculture between APEC economies and non APEC members in the Pacific, and Bay of Bengal region.
- A request to APEC to consider supporting additional workshops on grouper aquaculture, which would be catalytic in further development and increasing the impact of research and development of grouper aquaculture.

Finally, Hassanai Kongkeo (NACA) and Kee Chai Chong (BOBP) thanked the participants for their active participation in the workshop, and APEC, BOBP-FAO and NACA for sponsoring the workshop and looked forward to future cooperation in the development of the grouper network and seafarming in the region. Following these remarks, the workshop was closed.

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Annex 2: Workshop Programme

Monday, 17 April

14:00h **Registration**
19:00h **Official Opening Session**

- Opening Ceremony – Governor of North Sumatra
- Welcoming Remarks – Hassanai Kongkeo, NACA Coordinator
- Opening Remarks – Kee Chai Chong, Coordinator, BOBP Project
- Keynote Address – Untung Wahyono, Director-General, Directorate General of Fisheries, Indonesia

21:00h **Break**

Tuesday, 18 April Session I – Technical Session

08:30h **Background Papers**

- Overview of the workshop and objectives – Sugiri Elon, Director of Production, DGF
- Present status and strategy of Indonesia mariculture development – Sri Hartati Ramelan, Director of Seed Production, DGF
- Regional overview of marine finfish farming, with an emphasis on groupers and regional cooperation – Hassanai Kongkeo, NACA

10:00h **Tea Break**
10:30h **Grouper Aquaculture and Management Practices**

- Overview of Asia-Pacific Grouper Network (APGN) strategic research plan and ACIAR grouper project update - Mike Rimmer, QDPI
- Status of breeding and larval rearing of groupers - Joebert Toledo, SEAFDEC, AQD
- Breeding and larval rearing of barramundi cod (*Cromileptes altivelis*) in captivity - Ketut Sugama, Gondol
- Review of grouper diseases and health management strategies for grouper and other marine finfish diseases - Somkiat Khanchanakhan, AAHRI

13:30h **Lunch Break**
14:00h **Grouper Aquaculture and Management Practices (continued)**

- Feed and feed management practices - Renee Chou, AVA
- The availability and use of local ingredients in fish feed for humpback grouper grow-out - Taufik Ahmad, RICF
- Environmental management of mariculture: the effect of feed types on feed waste - Jim Chu, AFD

15:30h **Tea Break**
16:00h **Grouper Aquaculture and Management Practices (continued)**

- Grouper aquaculture in Myanmar – U Win Tin, DOF
- Grouper aquaculture in the Philippines – Westley Rosario, BFAR-NIFTDC
- Grouper aquaculture in Malaysia - K. Subramaniam, DOFM

Wednesday, 19 April Session I – Technical Session (continued)

08:30h Alternative Seafarming Species and Systems

- Development of new artisanal fisheries based on the capture and culture of postlarval coral reef fish - Cathy Hair, ICLARM
- Hatchery development options for marine fish - Peter Lauesen, SINTEF
- Perspective on future directions in cage culture related to Asia - Niels Svennevig, SINTEF

10:00h Tea Break

10:30h Session II: Special Session on Social and Economic Aspects of Grouper and Marine Fish Culture and Coastal Livelihoods

- Towards sustainable harvesting of live reef food fish species in Solomon Islands - Michelle Lam, MAF
- Preliminary report on the regional survey of fry and fingerling supply and current practices for grouper mariculture - Yvonne Sadovy, UHK
- An overview of the Komodo fish culture project - Peter Mous, TNC
- Seafarming and community development in the Philippines - Renato Agbayani, SEAFDEC AQD

12:00h Lunch Break

14:00h Session II (continued)

- Managing aquaculture sustainability using input-output relationships - Kee Chai Chong, BOBP
- Markets for cultured grouper and other marine finfish - Sudari, INFOFISH
- Assessing the sustainability of small-scale grouper culture in Southern Thailand - Natasja Sheriff, AIT

15:30h Tea Break

16:00h Session II (continued)

- Review of research program and prioritization of future research (followed by discussion session) - Mike Rimmer, QDPI; Hassanai Kongkeo, NACA; Michael Phillips, NACA

Thursday, 20 April Session III: Discussions and Development of Recommendations

08:30h The workshop split into three working groups. The working groups addressed the major issues raised during the proceeding technical and socio-economic sessions, with an emphasis on practical follow-up actions.

Working Group 1: Coastal Livelihoods and Socio-economic Issues
Working Group 2: Markets and Certification Issues
Working Group 3: Technology and Management

11:30h Working groups presented their findings to the workshop and the conclusions and recommendations were finalized and agreed by participants.

12:30h Lunch Break

14:00h Field Trip

Annex 3: Working Group Terms of Reference

Background

The focus of this seafarming workshop will be on marine fish farming and particularly grouper aquaculture. The workshop will explore management strategies required to support the sustainable development of seafarming in the Asian region, with emphasis on technology transfer and management strategies for the benefit of farmers and coastal people. There will be special sessions on diversification of seafarming systems and species, the role of seafarming in the livelihoods of coastal communities and an update on recent progress and further development of the APEC-NACA "Grouper Research and Development Network". The focus is on practical management and development strategies and evaluation of the potential of sustainable hatchery and farming enterprises for groupers and other marine finfish species to contribute to income generation and food security throughout the region.

Workshop Objectives

Objectives of the workshop are:

1. Awareness-building on sustainable management practices for seafarming
2. Identification of current needs and actions required for promoting sustainable seafarming in Indonesia and within the Asia-Pacific region
3. To review and identify strategies for ensuring that research on grouper aquaculture and seafarming leads to improved livelihoods of rural coastal communities
4. To evaluate the potential for development of sustainable localised hatchery production of marine finfish to support aquaculture development, and
5. To identify appropriate follow-up activities from the workshop, within Indonesia, and in other countries of the region, such as through collaborative research, training, extension, demonstration projects and other relevant activities

Working Group sessions

The workshop will split into three working groups. Working groups will address major issues raised during the proceeding technical and socio-economic sessions, with an emphasis on practical follow up actions, such as research needs, demonstration projects, staff exchanges, responsibilities of different centers and institutes, regional networking and others. Working groups are also expected to review recommendations and project ideas developed during the last APEC-NACA meeting in Hat Yai, and make recommendations for their further development and/or implementation as appropriate.

Working Group topics are given below.

Working Group 1: Coastal Livelihoods and Socio-economic Issues
Working Group 2: Markets and Certification Issues
Working Group 3: Technology and Management

Working groups will present their findings in the form of a short report to the workshop (at 11.30h on 20th April) and all participants will discuss the conclusions and recommendations.

Detailed Terms of Reference for Working Groups

Working Group 1: Coastal Livelihoods and Socio-economic Issues

This working group will specifically address the social and economic aspects of coastal seafarming development, including groupers. It should make recommendations for an appropriate development strategy for grouper (and marine fish culture) development based on the objective of improving livelihoods of people living in coastal areas. The Working Group should address the following specific issues:

- Discuss principles and approaches in seafarming management based on the objective of improving coastal livelihoods through seafarming development.
- Review the recommendations of the socio-economics group discussion from the Hat Yai APEC-NACA meeting, and make specific suggestions on their further development and implementation as appropriate.
- Discuss the strategies to be adopted to ensure that technical research findings lead to positive social and economic benefits to local communities.
- Evaluate the potential for development of sustainable local hatchery production of marine finfish to support aquaculture development now that small-scale nursing of grouper seems a possibility.
- Identify any additional requirements for promoting improvements in coastal livelihoods in Indonesia and within the Asia-Pacific region through sustainable seafarming.
- Develop specific follow up recommendations for ensuring seafarming research activities lead to improvements in coastal livelihoods. These can be targeted at follow-up in Indonesia, BOBP countries, and more broadly within the Asia-Pacific region, such as through collaborative research, training, extension, demonstration projects and other relevant activities to promote seafarming for coastal livelihoods.
- Identify useful exchange opportunities for personnel within and between countries in the region
- Discuss and make recommendations on a possible strategy to exchange experience on small pilot-projects focusing on coastal livelihoods, within the BOBP countries, and elsewhere in Asia-Pacific region.

Working Group 2: Markets and Certification Issues

This working group will specifically address market, trade and certification issues in coastal seafarming development, including groupers, and will make recommendations to ensure a development strategy is based on market needs. The following specific issues should be addressed:

- Review the recommendations of the markets and trade group discussion from the Hat Yai APEC-NACA meeting, and make specific suggestions on their further development and implementation
- Based on the discussions, develop specific follow up recommendations for management of seafarming based on market and trade issues. These can be targeted at follow-up in Indonesia, BOBP countries, and more broadly within the Asia-Pacific region, such as through collaborative research, training, extension, demonstration projects and other relevant activities.
- Identify specific follow-up project ideas to deal with key issues.

Working Group 3: Technology and Management

This working group will specifically address the technology and management aspects of coastal seafarming development, including groupers. Environmental issues should also be addressed.

- Based on the discussions during the workshop, identify general principles to be addressed in seafarming management.
- Review the recommendations and workplan of the technology group discussion from the Hat Yai APEC-NACA meeting, and make specific suggestions on their further development and implementation. Identify requirements to fill in any gaps.
- Review and make recommendations on the grouper virus project, to assist in its implementation.
- Review and make recommendations on the environmental management project and Codes of Practice project, to assist in its implementation.
- Identification of current needs and actions required for promoting sustainable seafarming in Indonesia and within the Asia-Pacific region, giving attention to diversification strategies.
- Evaluate the potential for development of sustainable localised hatchery production of marine finfish to support aquaculture development.
- Based on the discussions, develop specific follow-up recommendations for management of seafarming. These can be targeted at follow-up in Indonesia, BOBP countries, and more broadly within the Asia-Pacific region/APEC, such as through collaborative research, training, extension, demonstration projects and other relevant activities to promote seafarming for coastal livelihoods.
- Identify specific opportunities for involving the private sector in research and development activities.
- Identify specific follow-up project ideas to deal with key issues.

Annex 4: Workshop Presentation and Papers

Present Status and Strategy of Indonesian Mariculture Development

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Abstract

This paper describes the status of mariculture activities in Indonesia and the potential areas for future development. Information on the strategies adopted in Indonesia for mariculture development such as licensing, coastal planning, fish product quality and coordination and co-management are provided. Marine finfish culture and species, seaweed culture and pearl shell industry are also described.

Background

Indonesia's marine fish production grew 4.83% annually between 1994 and 1996, while aquaculture fish production grew 10.82% during the same period. Indonesian fish production was dominated by marine fishing but the annual growth rate of aquaculture was higher. Marine fisheries exploitation in some Indonesian waters (Java Sea, Malaka Strait and Makassar Strait) is beyond maximum sustainable yield, but in some areas the opportunity for fishing still exists. The Indonesian marine fisheries potential is approximately 6.2 mt per year, and fishing will not be developed further when exploitation reaches 80% of its maximum sustainable yield.

In the early 1990s, the Indonesian government decided to advance mariculture development in an effort to maintain the sustainability of marine resources. Fresh and brackish water fish culture increased from 219,130 ha to 337,200 ha. In 1996, production of fresh and brackish water fish had increased from 328,760 mt to 404,335 mt.

Further efforts should be focused on prevention of environmental degradation, resolution of conflicts in the use of coastal resources and production of high-quality mariculture products. The Indonesian government will develop regulations to promote the sustainable development of mariculture, including licensing, coastal planning and fish quality monitoring systems.

Potential Areas

Indonesia is an archipelago of 14,000 islands with a coast line of 81,000 km. It has great potential for mariculture. Many large estuarine areas with a clay bed substrate characterize Western Indonesia. Large bottom areas are potential sites for seabass and bivalve culture. The potential culture area for those species is 2.96 million ha and 2.95 million ha respectively. The eastern part of Indonesia (Nusa Tenggara and Maluku) is characterized by large coral reefs and is more suitable for seaweed culture (1.11 million ha), pearl culture and abalone at a depth of five to thirty meters (318,000 ha). The bottom sandy substrate and clay without large estuarine area in Sulawesi, Maluku and Irian is suitable for grouper culture (2.28 million ha) and sea cucumber (333,000 ha). The estimates were based on five km from the coastline and a water depth for specific species. The assumption was that the potential sites for finfish need a depth of five to thirty meters, five meters for oysters, and one to six meters for pen-culture.

Strategy for Mariculture Development

Mariculture development aims to increase export earnings, provide domestic food supply and to support sustainable coastal development. In achieving these objectives, mariculture development uses a strategy that is business oriented, industrially cultured, sustainable, and involves small-scale fishers in rural communities.

To support mariculture development in Indonesia, special attention should be given to the development of legal frameworks, financing, technology, marketing, infrastructure, human resources development, monitoring, controlling and surveillance. International cooperation is recommended to advance mariculture and attract investments.

Legal Framework

Strong and efficient legislation is required to further expand mariculture development. Legislation would provide a basis for conflict resolution among users. New regulations should be supported by strict enforcement of licensing requirements, coastal planning, environmental standards, and fish quality.

Licensing

The approval of licenses for mariculture, land ownership and company operation should be a simple procedure. The approval requirements should be focused on environmental awareness.

Coastal planning

To support the sustainable development of mariculture, coastal planning should be implemented. Elements of the plan should include sections on zoning, carrying capacity, environmental management, and disease control. It should further reflect the need for industrial development and improvement of livelihoods in coastal communities. The planning approach should be pro-active. The plan should address infrastructure improvement including transportation systems, communications, environmental information systems, mapping, harbor and fishing ports, cold storage, fish processing, advisory services, educational systems and other relevant topics. It should be made clear whether coastal planning is the responsibility of the government or the private sector.

Environment

Environmental awareness, protection of biodiversity, stakeholder involvement, and regional development needs will be important factors.

Fish product quality

Seafood products are sold in the international market so it is important to ensure their quality and safety. An internal QA/QC system for control of seafood products based on the HACCP and the ISO 9000/14000 standards should be established. This system must include eco-labeling and upstream and downstream QA/QC in the production chain. Certificates of origin should also be used.

Coordination and Co-management

Fisheries development is characterized by the involvement of medium to large companies as well as small-scale enterprises and fishers. There is a need to improve cooperation. In the governmental sector, there is a need to improve co-ordination which includes improving the institutional framework and co-operation between agencies. Private industry and small-scale fishers should co-manage mariculture development.

One approach is for several small units to join to form a larger unit which would be able to assist the fishers in management, marketing and technology transfer. This may help reduce risk and improve the total operation. A group of small-scale fishers may also benefit from stronger support from government agencies and better financing.

Financing

A major constraint to the development of this sector is lack of affordable financing. This applies to small-scale fishers and cooperatives in particular but also to larger concerns. Credit plans for small-scale fishers and cooperatives include only KUT and KKPA. They should be extended and simplified especially at the executing bank.

To attract private sector investments to mariculture, incentives should be offered, including measures to protect investments, linking farming rights to the site (giving value to the sites) through a license system and promoting the use of insurance to avoid significant losses in case of natural disaster. Financing by government is needed to support development of improved technology and technology transfer, supervision of management for small-scale fishers, infrastructure (public services), certification of fish products, monitoring, control and surveillance.

Technology

The technology for growing marine species in Indonesia is not well developed. Use of trash fish is a limiting factor. Artificial feeds are available to some extent but need to be improved. Use of fishmeal as the main ingredient is a problem in terms of both supply and price. The supply of fry and fingerling is insufficient and their quality is poor. The mortality at hatcheries is very high, which reduces the profitability. To improve the technology, bilateral or multilateral cooperation as well as private sector involvement has to be established. It would provide support to Mariculture Development Centers or other related institutions.

Existing Mariculture Development in Indonesia

Establishment of a Mariculture Development Task Force

A Task Force was established to help develop the mariculture industry. The Task Force includes officials from the Ministry of Sea Exploration and Fisheries, other related institutions and the private sector. It is chaired by the Director General of Fisheries. Their responsibility is to formulate a legislative framework as well as to establish and to implement a Mariculture Development Program including a monitoring, controlling and surveillance system. The Task Force will be supported by FAO under TCP/INS/8922.

Survey and Identification of Development Areas

Survey and identification of mariculture development areas are conducted to support coastal planning. The Directorate General of Fisheries is undertaking the survey and identification of development areas for mariculture in South Sulawesi and Southeast Sulawesi Provinces. The CoFish Project performed a survey in Riau islands and West Nusa Tenggara Provinces.

Establishment of a Pilot Project as a Model for Mariculture Development

Transfer of technology through a pilot project is performed. It covers the following:

- *Seabass culture*
  Riau Province support by CoFish Project
- *Seaweed culture*
  West Nusa Tenggara Province supported by Directorate General of Fisheries and Co-fish Project and North Sulawesi supported by Directorate General of Fisheries
- *Breeding and nursery of pearl shell*
  West Nusa Tenggara Province supported by SPL-OECF Project
- *Marine finfish breeding*
  Finfish breeding has been performed by the Technical Implementation Units of Directorate General of Fisheries located in Aceh, Batam, Lampung, Jepara, Sltubondo, Takalar, Lombok and Gondol (Bali)

Existing Mariculture Activities

Small-scale fishers conduct mariculture activities. They include grow-out of marine fish, seaweed culture and pearl shell industry.

Grow out of Marine Finfish

- The species are seabass *(Lates calcarifer),* groupers *(Cromileptes altivelis, Epinephelus fuscoguttatus, E. suillus, E. malabaricus, Plectropomus leopardus,)* and red snappers (*Lutjanus argentimaculatus,* or *Lutjanus johnii)* and *Cheilinus undulatus*
- Groupers and red snappers are cultured in the traditional way. The procedure is characterized by the use of wild seed, trash fish and mix-culture techniques. Only the private sector and a few fishers obtain the seed from a hatchery with floating net and monoculture techniques. The areas of grouper culture are in Aceh, North Sumatera (Nias and Sibolga), Riau Islands, Bangka Islands, Lampung, West Java, Karimunjawa Islands (Central Java), Teluk Saleh (West Nusa Tenggara), South Sulawesi, North Sulawesi and Southeast Sulawesi Provinces.
- Seabass culture is practiced in Bengkalis and Bangka by the private sector. Seabass are cultured using an intensive technology. The fishers use the fingerlings from a hatchery with a stocking density around 4,000 fingerlings per net (3x3x3m) and trash fish feed with the FCR around 10:1. There are 1,802 units of floating net in Bengkalis producing approximately 3,080 mt per year.
- For the other grouper culture, there is no statistical data available (other groupers are included in the marine fisheries production).
- Enhanced technology transfer, implementation of proper practices in marine finfish farming, artificial feed production for each species and fish processing technology are the essential issues in supporting mariculture development.

Seaweed Culture

- The main species of seaweed culture in Indonesia is *Euchema cottoni* and *Gracilaria sp.*
- Euchema cultures have been developed in Indonesia with bamboo rafts and long line technology. The seaweed is hinged every 25 cm with a density around 50-100 grams for each point. After forty-two to fifty-four days, they are ready to be harvested with 500 g to 1,000 g weight at each point. In 1997, total seaweed production in Indonesia was 157,000 mt (dry weight).
- Seaweed culture is propagated in areas that have a water depth of 30 to 60 cm during low tide. This is based on cutting seaweed from the previous harvest. Seaweed is cultured on Riau Islands, Lampung, West Java, Thousand Island (Jakarta), Bali, West Nusa Tenggara, North Sulawesi, South Sulawesi, Southeast Sulawesi, Maluku and Irian Jaya.
- For future development, the Indonesian government is looking into the possibility to obtain seaweed of better quality and to get post harvest seaweed technology to produce carageenan for the paint industry.

Pearl Shell Industry

- Pearl shell culture has been developed in eleven provinces and is operated by one hundred and eighteen private companies. The cultured species are *Pinctada maxima, P. margaritifera* and *Ptirea penguin. P. maxima* is the dominant species in producing pearl.
- Total pearl production in 1994 was 103 mt with an export value of US$ 20,873,000. The average price of a pearl (10 g weight) was US$ 2.00.
- The pearl culture industry faces problems due to the lack of wild shell supply. Some companies produce their own shells in their own hatchery. Those who do not operate hatcheries rely on wild seed collected by fishers. There is a strong indication that the wild seed stock is depleted. The government has been attempting to solve this problem by producing shell spat through fisher groups.

Table 1: Fisheries Production by Sub-sector

Sub-sector	1994	1995	1996	Annual growth rate (1994-1996)
Total	4,013,831	4,263,587	4,452,258	5.32%
Capture fisheries				
Marine fisheries	3,080,168	3,292,930	3,383,457	4.83%
Inland open waters	336,141	329,710	335,706	-0.05%
Sub total	3,416,309	3,622,640	3,719,163	4.35%
Aquaculture				
Brackish water	346,214	361,239	404,335	8.13%
Fresh water	140,098	162,198	182,918	14.27%
Cage culture	33,011	39,855	44,630	16.36%
Paddy field	78,199	77,655	101,212	14.82%
Sub total	597,522	640,947	733,095	10.82%

Regional Overview of Marine Finfish Farming, with an Emphasis on Groupers and Regional Cooperation

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Abstract

This presentation provides a brief overview of marine fish culture in the Asian region, some of the major issues and future directions for development of marine fish culture, with an emphasis on grouper culture. The paper then discusses some current NACA activities and future directions in regional cooperation for marine sea farming. The paper covers major topics, major issues and strategies for future development of marine fish farming; an overview of the status of marine fish farming, including groupers; current NACA activities in support of regional marine fish farming, future directions in regional cooperation; and workshop objectives and expectations.

Status of Marine Fish Farming, Including Groupers

Asia dominates the world in aquaculture production. Aquaculture in Asia is also extremely diverse in terms of species, technologies and farming systems employed. The wide range of geographic locations, habitats, and levels of national development are important influences on how Asian aquaculture has developed, and how it will develop in the future.

Asia's contribution to total world production in 1995 was:

- Finfish 89.1%
- Molluscs 82.4%
- Aquatic plants 99%
- Crustaceans both marine and freshwater 84%, and
- Miscellaneous animals and products 98.2%

Seven of the top aquaculture producing countries in the world are in Asia. In 1997, the combined production of twenty-two Asian countries and territories was 30.71 million mt valued at US$ 37.70 billion.

The annual contribution of finfish to total aquaculture production has been increasing in recent years. While the freshwater fish dominates the total finfish production, brackish water and marine fishes make up an important component in terms of production and value. Diadromous fish – mainly the milkfish (*Chanos chanos*) are very important in the Philippines and Indonesia. Marine fish production, while still relatively low in terms of volume, is important in several countries in Southeast Asia and East Asia. In terms of production, Japan and China were the leading economies. In 1997, China produced 255,000 mt from marine fish culture, with the major production centre in Guangdong. The cultured marine fish species in China include mullets, milkfish, groupers, snappers, seabreams, flounders and several other species. Similarly, around the region there is a diverse range of coastal finfish species being cultured. The cultured species include:

- snappers
- red seabream, which is an important species in Japan and China
- milkfish, which is a very common and important fish for food security, and
- rabbit fish, which is a small but locally important fish in some countries (it feeds low in the food chain)

It is noteworthy that there is such a range of species being cultured. This diversity provides very promising development opportunities. In addition, tuna is being tried for culture, although currently this farming relies on captured wild stocks. It is difficult to get accurate statistics on grouper production. One of the reasons is that is not easy to separate production from fish held for a few weeks in cages. Estimates suggest that China is probably the biggest producer of farmed grouper, and is probably followed closely by Indonesia. Other countries commonly produce 1,000 to 2,000 mt. Total regional production of farmed groupers is probably around 15,000 mt.

There are a number of species farmed, ranging from *Epinephelus akaara* and *E. awoara* in China to *E. coioides, E. tauvina, E. fuscoguttatus* and others in warmer regions. Add to this, small numbers of coral trouts *Plectropomus,* and various other species and it will quickly become apparent that there is a tremendous diversity of species involved. In fact, visits to any small-scale cage farmer in coastal areas around Asia will reveal a wide range of species, as the farmers mix availability of seed with market demand and other constraints, such as availability of credit and seasonal changes.

Groupers and other marine fish species are farmed in ponds or in cages in Asian coastal waters. Cage culture is an important means of fish production as it does not require land, and offers opportunities for landless people and fishers to become involved in fish culture. With the increasing difficulties of accessing coastal land, it seems likely that cage culture will become increasingly important in the future.

There are a diversity of cages in use in the region. These range from very small cages like extremely small bamboo cages used for holding groupers in Tam Giang Lagoon in Vietnam; to other more conventional inshore cages, often found in groups in sheltered inshore waters. There is also growing interest in larger cages which can be located in more open waters. It will be interesting to see how such cages survive the seasonal typhoons.

Major Marine Fish Development Issues and Strategies

Market Demand, Supply and Trade

By 2020 there will be about 4.2 billion people in Asia. In 1995, the region consumed 61 million mt of fish compared to Europe’s 12 million mt and North America’s 8 million mt. The consumption increase has been the fastest in the past five years. To maintain the 1995 average per capita supply of 17.2 kg, it will require nearly 70 million mt of food fish in 2020, both from capture fisheries and aquaculture. What this clearly points out is the heavy burden that has to be borne by aquaculture to meet the future demand for aquatic products. This requirement will have to come from both freshwater and coastal aquaculture.

Aquaculture in coastal areas supplies fish for local consumption and also inter-regional trade. The trade in live marine fish, particularly reef fishes, has been steadily growing, spurring work on their aquaculture. A market analysis done in1995 indicated the total seafood market in the main markets, Hong Kong and Southern China, was over 220,000 mt a year and that the market for the highest quality live reef fish was 1,600 to 1,700 mt per year. The study forecasted this to double every six years. In 1997, Hong Kong consumed 28,000 mt of live traded fish. More than a third in volume and half in value are groupers.

Thus, it seems likely that demand for higher value species, as well as lower value marine fish will increase in the future. However, a better understanding of market demand is required for aquaculture development strategies. There are a number of market and trade issues which will affect the future trade in groupers, and perhaps marine fish in general.

Environment and trade is one issue. The role of the fish farmer is changing from merely raising fish to being a part of a chain for the production and delivery of safe, high quality products to the consumer. Given the awareness in some markets of the need for products produced in an environmentally sound manner, it is possible in some – and almost certain in other - markets that aquaculture products will have to be marketed in ways that promote their production in an environmentally sound manner. This will require development of agreed principles, practical standards and guidelines to support implementation.

Another important issue, which has developed recently in the Pacific, is the plague of ciguatoxins associated with reef fish. This is a significant human health issue. A ciguatera-free source of fish derived from mariculture can provide a boost to mariculture industries in regions where wild-caught fish are often considered more valuable than farmed fish. This is an opportunity for aquaculture, but it will have to be supported by suitable awareness building and certification schemes that demonstrate to the consumer that the product comes from a safe aquaculture farm.

Technologies, Farming Systems and Management

There are a number of technical issues that need to be addressed as a part of the development of grouper farming and more generally marine fish farming in the region.

Grouper seed supply remains an important constraint, although recently there have been some promising successes. It is to be hoped that a concerted effort will lead to cultured stocks of some grouper species. Likewise, research on other marine species may lead to further development of systems for mass seed production and hatcheries of other species.

However, wild seed supply should not be ignored. There is a large number of people who collect wild seed from nature. The development of hatcheries may affect their livelihoods. Therefore, better understanding of this issue and the cost-benefit of options need to be looked into. Opportunities should be provided for people involved in wild seed collection.

There is also a need to look at alternative marine fish species. Of particular concern should be species which have a wide market and feed lower in the food chain than most of the predatory groupers. Likewise, there are opportunities for marine ornamental fish whose development may benefit small-scale producers. A more concerted effort on marine fish diversification is required to better understand and provide options for mariculture development in coastal areas, based on good understanding of market potential.

Feed usually accounts for up to 50% of production costs. Lately, due to concerns over the supply of fishmeal and oils, research has been focused on economically alternative sources of proteins and lipids. Improved management of feed efficiency is another area. The efficient use of feed resources, particularly using readily available local raw materials and minimizing environmental impacts, is highlighted. Fishmeal replacement, improvements in feeds and feeding technology, and the development of environmentally friendly, low pollution feeds need to be addressed.

Most grouper culture relies on trash fish. However, it is clear that an expansion of grouper culture in the region will require better feeds, which require less fish meal. It cannot be based on trash fish. Fortunately, some promising research work is providing avenues for the use of alternative feed supplies.

A distinction should be drawn between the production of feeds for commercially high value species and low value species. The high price of much of the species grown for export may justify investment involved in the manufacture, distribution, purchase and use of specially formulated feeds. However, much of the aquaculture in Asia involves smallholder-based production of low value species. In this case, the cost of feeds used is generally negligible and usually consists of cheap, readily available materials or the use of natural products, enhanced or otherwise. Research on marine fish species, which can be cultured using low value feeds and feed lower in the food chain could provide important benefits to small scale producers and should be pursued as part of a diversification strategy.

Currently, disease losses on grouper farms seem to be unacceptably high. Techniques for disease diagnosis, and techniques for prevention and control need to be developed, not least because grouper is a widely moved product. Work on seed quality has been relatively limited, and clear guidelines on the characteristics of high quality seed are not available. Some of the planned work on grouper viruses by Dr Somkiat from AAHRI should help fill important knowledge gaps. Likewise, the grouper health manual being prepared by SEAFDEC under the APEC-NACA grouper network project should provide support to extension officers and farmers in basic preventative health management which can be practiced on farm.

Most of the cage farms in the region are small-scale operations, although some involve very large numbers of small-cages. There is growing interest in larger scale, more offshore cage farms. For example, Malaysia has been experimenting with large offshore cages imported from Europe. Vietnam also has some trials. It will be interesting to see how such trials proceed. The cost of such systems may limit their application in some countries, so careful evaluation and possible development of low cost options needs to be looked into. Certainly, if cage culture is to grow in the region it is likely that further development of farming systems will be required, including farms that can be moved away from crowded inshore waters. The development of good farming practices and management systems will also be required to support sustainable development in the future.

Sea ranching is an area that deserves to be looked into. It may have an important role to play and should be further investigated, not least because of the possibilities for rehabilitation of stocks and providing social and economic benefits to small-scale fishers.

The growing scarcity of land-based resources is prompting the sector to look for alternative sites. The recent millennium conference in Bangkok emphasized that offshore cage culture may be one of the next frontiers, and a number of countries are making serious attempts at the system.

Regulatory and Planning Frameworks

The primary responsibility for aquaculture production usually falls within one government ministry or department. By contrast, the responsibility for the management of the coastal resources upon which aquaculture depends, particularly water and land, usually resides with several different departments of ministries. This situation inevitably gives rise to potential for conflict and lack of clarity in policy.

There are a number of international instruments that provide important guidance on such issues. The non-binding Code of Conduct for Responsible Fisheries may have a significant influence on the development of regulatory systems for aquaculture in the coming years. Article 9 of the Code deals with aquaculture development and sets out a wide range of relevant principles and criteria. In addition, the "Jakarta Mandate" adopted by the second Conference of the Parties to the Convention on Biological Diversity in 1995, provides useful guidance regarding environmental aspects which need to be taken into account in developing coastal aquaculture.

Options include the enactment of regulations under existing legislation and voluntary approaches such as guidelines and codes of practice. Malaysia, for example, is developing an integrated regulatory system for aquaculture in the short to medium term through development of a voluntary Code of Responsible Aquaculture Practices for marine cage culture supported by incentives. Whichever options are tried (as emphasised by Pak Untung), attention should be paid to an appropriate legal framework for sea farming development to ensure a sustainable and responsible growth of this potentially important industry.

An important issue that will have to be addressed is how to integrate marine fish farming into coastal management frameworks. There are some examples from Hong Kong, Japan and Korea, but limited experience on this subject elsewhere in the region. This subject will likely becoming increasingly significant in the future, but needs to be addressed at this stage of development.

Environmental Aspects of Aquaculture

Environmental issues have become an increasing concern for several reasons. One is the increasing resource use pressures in some coastal areas. More attention is being paid to the impact of aquaculture on the environment in recent years, induced in part by some well publicized 'crashes' in the shrimp industry, and also publicity of environmental and social issues surrounding aquaculture. Major environmental interactions of importance to Asian aquaculture include:

- Impacts of the external environment on aquaculture through coastal water pollution: interactions can be positive or negative
- Impacts of aquaculture on the environment which are likewise positive or negative, and
- Impacts of aquaculture on aquaculture which can lead to problems of sustainability, through self-pollution and disease

In Asia, guidance for improved environmental management practices are emerging for some types of farming practice. Management strategies need to be given attention at the level of a) technology and farming systems management b) adoption of integrated coastal area management approaches, and c) policy and institutional support. The understanding of coastal cage aquaculture is just beginning, and such issues will need more attention in the coming years. The developments of environmentally sound farming systems and management practices should be an important part of the future development of grouper and marine fish networks.

Less well known and documented is that coastal aquaculture in general can contribute to environmental improvement. Seaweed and mollusc culture may contribute to removal of nutrients and organic materials from coastal waters. Aquaculture can be an alternative source of employment for people involved in mangrove and other forms of habitat destruction. We are starting to see examples where marine cage culture is being promoted as part of a broader integrated coastal area development, including Marine Parks, where it can provide a valuable alternative livelihood option to destructive fishing practices.

The APEC Marine Resources Working Group meeting in Hong Kong in 1997 encouraged efforts towards the development of protocols and capacity for the culture of marine fish species. It included a focus on environmental and fish health issues, as well as alternative sources of feed, based on an understanding that grouper aquaculture can be an important alternative to destructive fishing practices. The specific recommendations from this Hong Kong meeting included the following statement:

> "Support economically viable and environmentally sustainable aquaculture of live reef fish. Specific action is to actively support, through budget allocations and domestic priority setting, collaborative research among expert centres on alternative sources of live reef fishes that do not depend on wild capture, in order to improve culturing capacity of reef fish species and develop experimental hatchery facilities."

It is to be hoped that future development of marine fish farming in the region does indeed support such objectives in reducing the environmental impacts of destructive fishing, and contributes in a positive way to environmental rehabilitation.

Coastal Livelihoods and Enterprise Development

Poverty alleviation is a critically important issue and must be addressed. There is an increasing recognition that small-scale social-oriented aquaculture can contribute to poverty alleviation among inland and coastal communities through income and food generation. This is an important concern of this workshop. We look for guidance [from the group] on appropriate management practices and approaches that address the needs of poorer people in coastal communities. Likewise, attention must be given to ensuring the results from research benefit producers. Much research is carried out in isolation from the needs of the users; the small farmers, fishers and the private sector.

General Conclusions

In general, marine fish culture will grow in the future due to market demand. There are some key management issues that need to be addressed. The overall outlook is good, but there will have to be a strategic approach to development in a sustainable and responsible way.

Regional Cooperation

There are a number of reasons for promoting regional cooperation in sea farming development. These include the diversity of farming systems and species that cannot be addressed by one research institute; the diversity of the issues to be tackled; the importance of avoiding duplication of effort and making cost-effective use of resources. NACA was established as an intergovernmental organization, and the justification for regional cooperation remains as strong as ever. The recently concluded "Conference on Aquaculture in the Third Millennium" has strongly emphasized the importance of strengthened cooperation in the new millennium.

NACA has been involved in several activities to promote cooperation in sea farming and grouper aquaculture. In the 1980s, NACA undertook a sea farming development and demonstration project to initiate cooperation among sea farming centres in the region. Indonesia took a similar role in this project.

More recently, special attention has been given to the development of sustainable grouper aquaculture operations. Many research groups are working on grouper breeding and larval rearing, but many are also repeating much of the same type of work and facing similar constraints, particularly in nursing. Meetings in 1998 and 1999 clearly defined some of the key constraints and led to the development of a more comprehensive programme of research cooperation aiming to overcome some of the constraints in grouper breeding and grow-out. It is hoped that further cooperation with APEC, Bay of Bengal countries and other interested parties will lead to improved and more structured cooperation in grouper aquaculture. Genuine cooperation among groups with common interests in this subject can do a lot towards overcoming the various constraints and lead to the sustainable development of grouper and marine fish aquaculture in coastal areas. Cooperation being promoted through this networking approach (covering research, information exchange and capacity building) can and should be broadly applied in promoting marine aquaculture in the region.

ACIAR is now providing support to the development of grouper culture through a cooperative project involving Indonesia, the Philippines and Australia. NACA has the responsibility for wider dissemination and coordination of activities.

Following the recommendations of the Marine Resources Working Group, APEC is supporting an APEC-NACA network approach as it provides the best opportunity to achieve results whilst reducing the overall cost of research and preventing duplication of effort. The objectives of the project are as follows:

- Through the establishment of a regional research network, develop the capacity to establish a sustainable grouper aquaculture industry which will benefit all collaborating economies, and through this:
    a) Seek to provide an alternative source of income and employment to people currently engaging in dangerous and illegal fishing practices.
    b) Protect endangered reefs and reef fish from the pressures of illegal and dangerous fishing practices.
    c) Develop a new aquaculture industry with significant export potential and economic benefit to a diversity of stakeholders.
    d) Reduce substantially the current reliance on wild-caught fingerlings for aquaculture purposes because capture of wild juveniles is probably unsustainable, and is sometimes carried out using destructive fishing

techniques which can have a significant impact on the long-term status of reef fish stocks.

- Through APEC involvement, the expansion of the ACIAR project on collaborative research into grouper culture has been extended to more economies in the Asia-Pacific region.

NACA wishes to see such collaborative approaches further developed and promoted within the region, building on the above successes and the sea farming centres within the NACA network. The development, not only of grouper culture, but more broadly that of marine fish farming, deserves a special and concerted networking effort, which would build on the strengths of past experience and centres of excellence. We also have to build firm bridges to the private sector in such cooperation.

Overview of Asia-Pacific Grouper Network (APGN) Strategic Research Plan and ACIAR Grouper Project Update

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Abstract

This presentation provides the background of the development of Asia-Pacific Grouper Network, and an overview of the APGN strategic research plan and ACIAR Grouper Project activities. The research outcomes of some activities on larval rearing and grow-out diet development are also provided.

Overview of APGN Strategic Research Plan

The Asia-Pacific Grouper Network (APGN) was established in April 1998 at a meeting of grouper aquaculture researchers in Bangkok, Thailand. In response to concerns that there was considerable overlap of research effort in grouper aquaculture in the Asia-Pacific region, one of the recommendations of the meeting was that:

- Coordinated grouper research in the Asia-Pacific Region should be established. This could be facilitated by:
  a) Establishment of a research program comprising institutional and collaborative projects to address the key issues identified in this workshop. The program would be facilitated by NACA in cooperation with other institutes.
  b) Agreements by institutions to participate in a regional coordinated research program on grouper aquaculture technology development.
  c) Additional training opportunities, for example through staff exchanges and short-term attachments at participating institutions.

The overall research program for the Asia-Pacific Grouper Network has been drafted and will be presented for discussion. The outline of the research program is as follows:

1. Production technology
   1.1 Broodstock
   1.2 Larviculture
   1.3 Nursery
   1.4 Grow-out
2. Environment
3. Marketing
4. Food supply, certification
5. Socio-economics, livelihoods
6. Fish health

One of the desired outcomes [of this workshop] is to address the second part of the recommendation, ‘agreements by institutions to participate in a regional coordinated research program on grouper aquaculture technology development’.

ACIAR Project FIS/97/73 'Improved Hatchery and Grow-out Technology for Grouper Aquaculture in the Asia-Pacific Region'

Project Objectives

The overall objective of the ACIAR project is to increase grouper production in the Asia-Pacific region by developing improved hatchery and grow-out technology. The project has three major components.

Larval Rearing of Groupers

The objective of this component is to improve growth and survival of groupers during the hatchery phase. The research concentrates on developing a better understanding of the capacity of grouper larvae to digest various live prey organisms, and the nutritional composition that must be provided by live prey. This information is being used to assess the suitability of different live prey organisms at different stages of the larval rearing process, and to develop improved nutritional profiles for live prey organisms. Direct enhancement of larval nutrition, using artificial diets, is also being examined. These results will be integrated with other studies on environmental factors affecting grouper larvae to develop an improved methodology for larval rearing of groupers.

Diet Development for On-growing of Grouper

The objective of this component is to develop compounded feeds for grouper grow-out that have low environmental impact, a low content of fish products, and are as cost-effective for the on-growing of grouper as the alternative of using trash fish.

This is being addressed by acquiring nutritional information on feeds available for diet manufacture, characterizing the requirements of groupers for key nutrients and demonstrating the cost effectiveness of the compounded feeds. The research plan recognizes that grow-out nutrition work in Australia can only be done subsequent to the successful larval rearing of the fry. This constraint does not apply for the overseas collaborators, where collection of fry from the wild is permitted.

Support for the Grouper Aquaculture Research and Development Program

The objective of this component is to add value to existing grouper aquaculture R&D efforts in the Asia-Pacific region by improving communication and promoting collaborative research between regional laboratories and agencies.

NACA, in cooperation with participating institutions, is preparing a cooperative grouper aquaculture research and development program based on the recommendations and specific research detailed in the proceedings of the Grouper Aquaculture Workshop held in Bangkok in April 1998. The program will be circulated to respective institutions to seek institutional support and commitment. NACA, in cooperation with participating institutions, will continue to seek funding support for specific projects under the Grouper Aquaculture Research and Development Program, with particular emphasis on the development of collaborative research and development projects. NACA is facilitating enhanced communication amongst grouper aquaculture researchers by pursuing reports of research findings from participating institutions, and by compiling and publishing this information in regional aquaculture magazines and on the NACA grouper web site.

Participating Institutes

Formal participants in the ACIAR Grouper Culture Project are as follows: Department of Primary Industries, Queensland

- Network of Aquaculture Centres in Asia-Pacific
- Research Station for Coastal Fisheries, Gondol, Bali, Indonesia
- Research Institute for Coastal Fisheries, Maros, Sulawesi, Indonesia
- Southeast Asian Fisheries Development Centre, Aquaculture Department, and
- Commonwealth Scientific and Industrial Research Organisation, Division of Marine Research, Australia

Project Structure

Based on activity proposals from the partner laboratories and discussions held during the initial project visits and project meetings, the grouper project has been divided into the following activities:

1. Project Administration
    - 1.1 Project meetings
    - 1.2 Training
    - 1.3 Calibration exercises
    - 1.4 End-of-project workshop
2. Larval Rearing
    - 2.1 Pre-feeding larvae and environmental factors
    - 2.2 Larval nutrition
        - 2.2.1 Nutritional composition of live feeds
        - 2.2.2 Nutritional requirements of grouper larvae
        - 2.2.3 Natural and artificial diets
    - 2.3 Development of digestive tract and enzymes
        - 2.3.1 Histology
        - 2.3.2 Digestive enzymes (qualitative)
        - 2.3.3 Digestive enzymes (quantitative)
    - 2.4 Verification – larval rearing
        - 2.4.1 Intensive larval rearing
        - 2.4.2 Semi-intensive larval rearing
3. Grow-out Nutrition
    - 3.1 Inventory of feed ingredients
    - 3.2 Nutritional composition
        - 3.2.1 Chemical analyses
        - 3.2.2 Digestibility of key ingredients
    - 3.3 Nutritional requirements
        - 3.3.1 Protein; P:E
        - 3.3.2 Fatty acids
        - 3.3.3 Phospholipids
    - 3.4 Fishmeal replacement
    - 3.5 Diet validation
    - 3.6 Economic evaluation
4. Communication and Coordination
    - 4.1 Research program development
    - 4.2 Research coordination

4.3 Dissemination of results

Project Progress

Significant progress has been made in a number of areas of the ACIAR Grouper Project over the first six months of the project (to January 2000). These are briefly summarised below:

Larval Rearing

Research on pre-feeding larvae at SEAFDEC has demonstrated that incubation density affects the proportion of abnormal *Epinephelus coioides* larvae; eggs incubated at 200–400 per litre had lower numbers of abnormal larvae (6.5% to 8.5%) than those incubated at 800 to 1,600 per litre (29.5% to 30.8%).

Larval rearing trials at GRSCF with *Cromileptes altivelis* using a combination of SS- and S-strain rotifer, brine shrimp, and artificial larval diets, gave an average survival of 29.4% (range 23.6% to 53.7%) following the exclusion of VNN-positive broodstock. *C. altivelis* larvae reached 29.2 mm ± 0.21 mm after fifty days.

Grow-out Diet Development

Research at RICF Maros has provided a wealth of information on potential ingredients for grouper grow-out feeds along with detailed chemical analyses of these ingredients.

The apparent digestibility of key feed ingredients has been determined with *E. coioides* in a series of experiments at SEAFDEC. The data are being used to develop practical diets for *E. coioides*. Promising results have been achieved using local meat and bone meal, Protamino Aqua (processed meat solubles), white cowpea or ipil-ipil meals as partial replacements of fishmeal. Replacement of all of the fishmeal with Protamino Aqua was found to have no adverse effect on growth and survival of *E. coioides*. At Gondol, growth rate of *C. altivelis* was found to decline when soybean meal was isonitrogenously substituted for fishmeal at rates of 20% or more.

The dietary protein requirement of *C. altivelis* was found to decrease from ~54 to 45% as fish size increased from initial weights of ~5 and 17 g in studies at Gondol and Maros.

Asia-Pacific Grouper Network

Membership in the APGN continues to grow. A dedicated Grouper Culture session at WAS'99 in Sydney showcased the development of the network and the research and development work being undertaken by network participants. Presentations at other regional conferences and workshops have encouraged participation in the APGN.

The electronic grouper newsletter, developed to facilitate information exchange within the network, has been extremely popular and now has over one hundred subscribers. A site for the ACIAR Grouper Project has been added to the NACA Grouper web site.

Further Information

For further details of the results of the ACIAR Grouper Project, see http://www.enaca.org/aciar/

The next project meeting will be held in Cairns, Queensland, Australia, in late July 2000. Anyone interested in attending, please see Mike Rimmer during the workshop, or contact by email: mike.rimmer@dpi.qld.gov.au.

Status of Breeding and Larval Rearing of Groupers

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Abstract

Attempts to breed groupers in captivity started about four decades ago. Ukawa et al. (1966) described the successful fertilization and embryonic development of the red grouper Epinephelus akaara*. Fueled by the high market value of live groupers and the inconsistent supply of juveniles from the wild, research on broodstock development and seed production of grouper has been intensified since the1980s. Natural or induced spawning in groupers was reported in* Epinephelus tauvina *(Chen et al. 1977, Hussain and Higuchi, 1980),* E. malabaricus *(Ruangpanit et al. 1986),* E. salmoides *(Kungvankij et al. 1986),* E. fuscoguttatus *(Lim et al. 1990),* E. suillus *(*=E. coioides*) (Toledo et al. 1993),* E. polyphekadion *(Sugama, pers. com), and* Cromileptes altivelis *(Sugama and Ikenoue 1999). Despite these developments, hatchery production of groupers remains unreliable. This paper reviews the status of breeding and larval rearing of groupers. Much of the information presented derives from the research and development studies on* E. coioides *at the Aquaculture Department of the Southeast Asian Fisheries Development Center.*

Broodstock Management

Initial broodstock are mostly caught from the wild; preferably in fish traps. Because groupers are protandrous hermaprodite (Shapiro, 1987), they mature first as females and transform into males as they grow larger. The difficulty in obtaining and maintaining large-sized males from the wild led to the development of methods to induce sex-inversion. A dose of 1 mg methyltestosterone (mt)/kg of food has resulted in sex-inversion to male in *E. tauvina* and was successfully used to fertilize eggs (Chen et al. 1977). Sex inversion was also achieved within five months in *E. suillus* (=*E. coioides*) by giving bi-monthly intramuscular injections of 17-alpha mt at a dose of 0.5 and 1.0 mg/kg BW (Tan-Fermin et al. 1994). In most cases, sex-inversed males reversed back to females after hormone treatment was terminated (Tan-Fermin, 1992). Marte et al. (1995) obtained functional males within seven to ten weeks after implantation of silastic capsules containing mt to adult *E. coioides* females at a dose of 4 mg/kg BW. Viable eggs were obtained from natural spawning of these sex-inversed males. Sex change in female groupers may also be accelerated by social control. *E. coioides* females were sexually changed into males by social control after two and four months in concrete tanks and floating net cages (Quinitio et al. 1997).

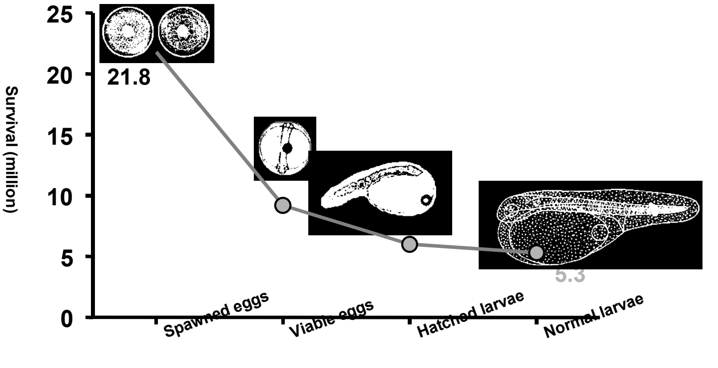
Groupers are highly fecund fish. A mature female (5.3 kg) *E. suillus* paired with two spermiating males (6 kg and 6.5 kg) successively spawned five to ten times a month from July to October 1990. Six mature females (3.5 kg to 5.0 kg) and four mature males (7 kg to12 kg) maintained in a 50-mt tank spawned successively five to seventeen times a month for almost a year (except in May 1991). Spawning is highly predictable with the onset of monthly spawning cycle within three days before or after the last quarter moon. The number of eggs collected, mean fertilization rate, and mean hatching rate in the tank and floating net cage each month varied from 0.5 to 15.8 million and 2.3 to 3.9 million, (67% to 88% and 72% to 89%), and (2% to 81% and 29% to 68%) respectively (Toledo et al. 1993).

High variations in the quantity and quality of spawns may be related to fluctuations in environmental conditions and the inconsistent nutritional quality of trash fish fed to broodstock. The addition of commercial enrichment products of highly unsaturated fatty acids into trash fish did not improve the quality of spawned eggs (Quinitio et al.1996).

Larval Rearing

Figure 1 shows a typical survival curve of naturally spawned *E. coioides* eggs to hatching. Only 5.3 million normal, newly-hatched larvae were obtained from 21.8 million spawned eggs collected. Depending on the quality of the larvae, up to half of the larvae may die before the onset of feeding. Most of the dead eggs are either unfertilized or those with aborted embryonic development at the blastula or gastrula stage. Hatching of fertilized eggs and survival of starved larvae were significantly improved when fertilized eggs were collected and handled at the early cleavage or "eyed" stage (Caberoy et al.1999). Preliminary results also indicate that the percentage of abnormal larvae (curved and relatively smaller larvae) is significantly higher at incubation densities of 800 and 1,600 eggs/l than at 200 and 400 eggs/l. Hatching rates and percentage of normal larvae are higher at aeration volume of 100 ml/min than at 500 and 1000 ml/min (Caberoy, pers. com). Experiments to determine the effects of aeration, temperature, salinity, and light intensity on the survival of grouper embryos and early stage larvae are ongoing.

Figure 1. Survival profile of naturally spawned *E. coioides* eggs to hatching



Thyroid hormone levels in fish eggs and larvae have been considered as determinants in egg and larval quality (Lam, 1994). Lam (1994) reported that both tetra-iodothyronine (T_4) and tri-iodothyronine (T_3) levels are higher in buoyant or viable *E. tauvina* eggs than in non-buoyant or non-viable ones, which suggests the significance of thyroid hormones on egg viability. In a follow-up study, Tay et al. (1995) observed that immersion of *E. tauvina* eggs in 0.5 ppm T_3 and 0.5 ppm cortisol enhances the survival of yolk-sac larvae compared to those immersed in either T_3 or cortisol alone.

Despite the advancement in larviculture techniques for other marine fish, heavy mortality in grouper larval production is still common between three to nine days after hatching. Compared to other marine fish such as seabass and milkfish, grouper larvae have relatively smaller mouth and body sizes, as well as poor endogenous reserves at the onset of feeding (Kohno et al. 1997). Survival at the early feeding stages could be improved by providing appropriate prey size. Larvae of *E. fuscoguttatus* could start feeding directly on S-type rotifer, while the smaller SS-type rotifer are provided at the onset of feeding of *E. tauvina* (Lim, 1993). Oyster trocophores enhanced larval survival in *E. striatus* when used in combination with rotifers, possibly by improving size selectivity and dietary quality (Watanabe et al. 1996).

Although the provision of appropriate prey size to early stage grouper larvae improves survival, high mortality until metamorphosis persists. In addition, "shock syndrome", which is a sign of nutritional deficiency, is commonly observed. Survival and resistance to stress in marine fish larvae may be enhanced by improving the nutritional quality of live food (Watanabe and Kiron 1996, Rainuzzo et al.1997). Better growth, survival, and stress resistance were observed in grouper larvae fed with rotifer and *Artemia* previously enriched with emulsions containing high levels of highly unsaturated fatty acid (HUFA) (Lima and Chao 1990; Lim, 1993).

Based on the results of previous studies (Duray and Kohno 1990, Duray et al.1995, Duray et al. 1996, Chavez et al. 1996), a protocol for the intensive larval rearing for *E. coioides* was developed (Duray et al. 1997) (Figure 2). Newly-hatched larvae are stocked at a density of 30 ind/l. Larvae are initially fed with HUFA and vitamin C enriched with small-sized rotifers at 20 ind/ml from days two to twenty (day of hatching = day 0). The rotifer density is reduced to 10 ind/ml on day twenty-one upon addition of newly-hatched *Artemia* nauplii. From days twenty-five to fifty, larvae were fed increasing sizes of *Artemia*. Larvae are gradually weaned to minced fish from day forty-five. *Artemia* are enriched with commercial products containing high amounts of HUFA before feeding to the larvae. *Chlorella* is added daily to the larval tanks as food for rotifer and as water conditioner. Larvae are harvested on day twenty-four and re-stocked in a clean tank at one to three larvae per litre with a salinity of 24 ppt. The water management scheme is summarized in Figure 2.

Semi-intensive larval rearing for *E. coioides* was also developed (Figure 3). This method employs minimal water change, lower density of larvae, and the use of copepod nauplii in combination with rotifer as initial food. To propagate copepod nauplii, sub-adult and adult *Acartia* or *Pseudodiaptomus* are collected from brackish water ponds and inoculated in the larval tanks two to three days before stocking of newly-hatch larvae. Feeding incidence in early stage larvae provided with copepod nauplii was consistently higher than for those fed rotifers only. Early stage grouper larvae preferred copepod nauplii to rotifer. Survival and growth of larvae fed copepod nauplii and rotifers are also higher than for those fed rotifers only (Doi et al. 1997, Toledo et al. 1997). Table 1 (Toledo et al. 1999) shows that *Pseudodiaptomus* and

Acartia contain high levels of HUFA particularly docosahaexanoic acid (DHA). DHA is known as an essential fatty acid for marine fish larvae (Watanabe 1993; Watanabe and Kiron 1996). The appropriate density of copepod adults and nauplii to sustain the food requirements of early feeding larvae was also determined (Toledo et al. 1999). Studies to develop production techniques for *Acartia* and *Pseudodiaptomus* should be accelerated. The possibility of using copepods as a supplement or as total replacement for *Artemia* during advanced larval stages should be explored.

Figure 2. Generalized feeding and water management scheme for intensive rearing of grouper larvae

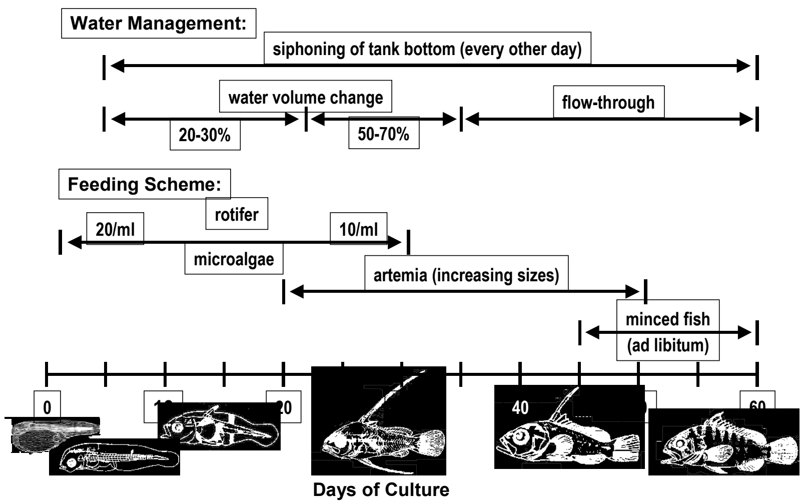
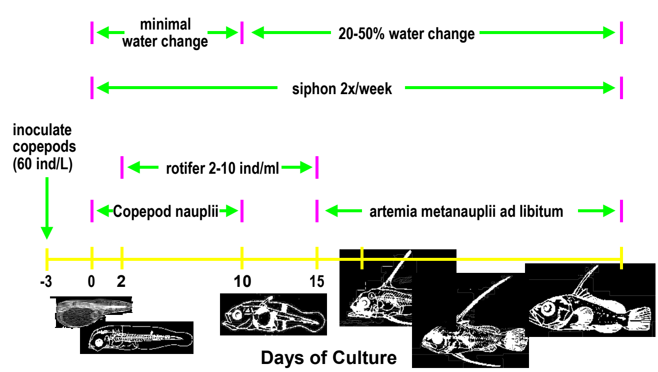


Figure 3. Feeding and water management scheme in semi-intensive rearing of grouper



Source: Toledo et al.(1999)

Table 1: Fatty acid composition (%area) of food organisms used in the early feeding stages of grouper *E. coioides* larvae

Fatty Acid	Pseudodiaptomus	Acartia	Oithona	Rotifer
Σ Saturate	42.86	44.17	63.01	39.94
Σ Monoene	15.33	8.84	15.95	29.76
Σ n-6	7.72	8.14	1.60	10.50
Σ n-3	29.55	36.01	12.18	13.88
Σ n-3 HUFA	23.75	34.48	10.74	13.35
n-3/n-6	3.83	4.42	2.65	1.11
DHA/EPA	1.37	2.64	1.28	0.02
Source: Toledo, et al. (1999)				

Although survival during the early larval stages has been improved, survival of grouper from hatching until metamorphosis is still generally low at about 3% to 5%. Grouper larvae develop elongated dorsal and ventral spines, swim in the water column, and feed on zooplankton as they grow. During metamorphosis, the spines are gradually resorbed, pigmentation pattern forms, habitat changes from pelagic to bottom dwellers, and weaning to trash fish becomes possible (Fukuhara and Fushimi, 1988). The process of metamorphosis in grouper requires more than two weeks to be completed and larvae are known to be extremely sensitive to stress at this stage (Doi et al. 1991). At this stage until metamorphosis (days twenty-five to fifty), high mortality is commonly experienced. Metamorphosis in *E. coioides* larvae can be accelerated by thyroid hormones T_3 or T_4. The percentage of metamorphosed larvae significantly increased when twenty-five days old larvae were fed with *Artemia* enriched in 0.5 ppm T_3 for six hours (Tay et al. 1994). The response of the larvae to both hormones was dose-dependent (de Jesus et al. 1998). Three or four week old larvae immersed in 1 ppm T_3 or T_4 metamorphosed within two days; three to four days in larvae exposed to 0.1 ppm; five to six days in larvae treated with 0.01 ppm while untreated controls took ten to twenty-one days to complete metamorphosis. In four-week old larvae, survival after metamorphosis was significantly higher in treated fish than that in untreated fish. Likewise, survival was higher at lower doses tested.

Experimental results are presently verified in large tanks at SEAFDEC AQD (Duray, pers. com.). Viable grouper eggs are directly stocked in 5 or 10-mt larval rearing tanks. Depending on the hatching rate, the initial stocking densities varied from two to thirty-six larvae per liter. Live food was enriched with vitamin C-fortified DHA Selco. Survival rates on day twenty-one ranged from 11% to 56%. Day twenty-one larvae were treated with thyroxin either by immersion (0.01 ppm) or by bioencapsulation in *Artemia* (0.5 ppm) for five consecutive days. Average survival after thyroxin treatment was 53% by immersion and 59% by bioencapsulation. Larval survival from hatching to day thirty-five ranged from 5.4% to 29.8%. Survival rate at harvest (day fifty-five, about two inches) was 3%.

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Breeding and Larval Rearing of Barramundi Cod (*Cromileptes altivelis*) in Captivity

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Abstract

Barramundi cod grouper, Cromileptes altivelis*, spawned naturally in captivity without the use of hormones or other treatment. Spawning occurred four to seven times a month throughout a year and mostly took place at the new moon phase with water temperature ranging from 27.1 °C to 28 °C. It is estimated that a female laid about 200 to 1,200 x* 10^3 *eggs in each spawning. The hatched larvae were reared in 4 to10* m^3 *rectangular concrete tanks and fed initially on rotifer,* Brachionus plicatilis*, followed by* Artemia *nauplii and finally weaned onto an artificial diet. Larval rearing trials for growth and survival to fifty days produced juveniles of 24.1 mm to 25.3 mm in average length, at a survival rate ranging from 2.63% to 53.9%. High mortality of the larvae occurred during the initial two to five days after hatching; cannibalism was not frequently observed at the juvenile stage. The results demonstrated the possibility of breeding mouse grouper under captive conditions. However, methods of Viral Nervous Necrosis (VNN) control to improve the larval survival rate have to be pursued further for commercial farming of this species.*

Introduction

Cromileptes altivelis has several common names such as humpback grouper, mouse grouper, barramundi cod grouper, polka dot grouper and Grace Kelly grouper. This species commands the highest price among groupers especially for the live fish trade in Southeast Asia. In Indonesia (Riau, Lampung and West Nusa Tengara Provinces) the fish are farmed using simple floating net cages stocked with wild caught seed and fed with fresh trash fish (Sugama et al. 1986).

Control of spawning and hatchery rearing of this fish is becoming commercially feasible. A small number of juveniles have been produced at Gondol Research Station for Coastal Fisheries. They have been used for further rearing in Lampung Coastal water using floating net cages. The juveniles used for culturing mostly come from local coastal waters. The supply of juveniles is not sufficient and is a major limiting factor in the development of *C. altivelis* culture. The shortage of larvae, scarcity of juveniles from the wild and high market value of adult fish and juveniles have encouraged many countries in Asia to start research programs on grouper fry production. For other groupers, some authors reported spawning success with various grouper species, *Epinephelus polyphekadion* in Saudi Arabia (James et al. 1997), *Epinephelus aeneus* in Israel and Arab (Kolkovski 1998, Hassin et al. 1997), *Epinephelus coioides* in Thailand (Yoshiro 1998), Malaysia (Ali 1998) and Philippnines (Toledo 1993), *Epinephelus fuscoguttatus* in Indonesia (Diani and Slamet, 1994). However, the progress in grouper fry production technology has been slow due to the difficulty of raising the larvae to metamorphosis. Although better results were reported in more recent studies, the survival rates were still inconsistent. For example, survival rates fluctuating between 2% and 10% were reported for *E. tauvina* and *E. fuscoguttatus* in Singapore (Lim, 1993), and between 1.6% and 4.7% for *Epinephelus polyphekadion* in Saudi Arabia (James et al. 1997).

The complete larval development of humpback grouper *C. altivelis* has been described by Kumagai et al. (1998). No success has been reported so far on rearing of the larvae. The present study reports the successful results on natural spawning in captivity of barramundi cod during 1998-1999 and describes mass larviculture.

Materials and Methods

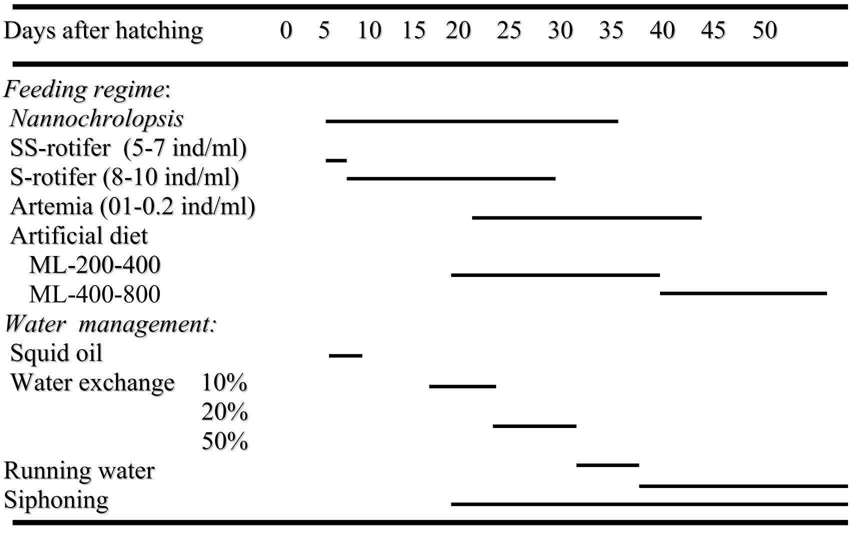
Humpback grouper broodstock were collected from the wild and acclimated to captivity for about two to four weeks before being stocked in spawning tanks at a sex ratio of 1:4 (male:female). Mature females were smaller than males and weighed between 1.6 kg and 2.4 kg each whereas male broodstock weighed between 2.8 kg and 3.2 kg each. Twenty five fish (5 males and 20 females) used for spawning studies were stocked in a circular tank (60 m^3 capacity, 2.15 m water depth). The spawning tank was equipped with a water inlet and outlet and an aeration system. It had a flow-through by changing 300% to 400% of the tank water daily and maintained a natural photoperiod. The water temperature and salinity during preconditioning and spawning period were ambient (27-28 ^oC and 34-35 ppt). Fish were fed to satiation four times a week, three times by trash fish (mainly *Clupeidae* and *Scombridae*) and one time with squid. The feed was supplemented with a vitamin mix at 1% of feed.

Eggs were collected from the spawning tank through the outlet with a fine net (400 μm). The eggs were then transferred into 0.5 to 1.0 m^3 transparent circular tanks for incubation. Unfertilized eggs settled to the bottom of tank and were removed by siphoning. Newly hatched larvae (0-DAH) were stocked in four, 10 m^3 capacity of larval rearing tanks with an initial density of five to fourteen larvae per liter.

The sea water used in the hatchery was pre-treated using sand filters. The water salinity ranged from 34 ppt to 34.5 ppt, and water temperature ranged from 28^{o}C to 30^{o}C. The larval rearing was carried out in the same tank for fifty days. Live food for the larval rearing consisted of microalge, *Nannochloropsis* sp., SS-type rotifers (size 80-100 μ), S-type rotifers (120-240 μ) and *Artemia* nauplii. Artificial diets were introduced prior to feeding *Artemia* nauplii. The larval rearing protocol is summarized in Figure 1.

The *Nannochloropsis* was introduced in the larval rearing tanks after twenty-four hours of stocking the larvae (1-DAH), the alga cell density was maintained at 300-400 x 10^3 cell/ml. The SS-type rotifers, *Brachionus plicatilis*, were introduced on day two when the larvae partly absorbed their yolk. The SS-type rotifer density in the larval rearing tank was maintained at 5-7 ind/ml during 2-5 DAH. The S-type rotifers with a density of 8-10 ind/ml was maintained during 6-20 DAH and the density gradually decreased as the rate of rotifer consumption by the larvae increased and eventually rotifers disappeared by day twenty-five. From day fifteen onward, small-size commercially formulated diet (Nippai, ML-Powdered) with a particle size of 200-400 μ was used. The feed size was gradually increased from 400 to 800 μ from day thirty to day fifty. From day seventeen onward, newly hatched *Artemia* were introduced with a density of 0.1-0.2 ind/ml. Before introduction to the larval rearing tanks, one day old *Artemia*, were treated or enriched with "Yugen" or "Super Celco" to increase their nutritional value. On the days when the fish were fed artificial diets and *Artemia*, 20% to 50% of the rearing water was changed once daily. At day thirty, running water at an exchange rate of 100% per day was used to avoid water quality problems. After fifty days, all surviving juveniles were transferred to other tanks for further growth.

Figure 1. Tank management procedures for the larval rearing of Barramundi cod grouper, *Cromileptes altivelis*



Results and Discussion

After a six months acclimation period under natural environmental conditions, wild humpback grouper spawned naturally throughout the year. Natural spawning took place every month (four to seven times a month), and mostly occurred in the new moon phase (Figure 2). The fish usually spawn at night between 10:00-12:00 o'clock in a water temperature range of 27.1°C to 27.8°C. The total number of eggs released in each spawning were estimated at 0.2-1.2 million. Only fertilized, floating eggs were collected. Fertilization rates could not be determined because the tank was a flow-through system. The fertilized eggs of *C. altivelis* were non-adhesive and pelagic. The newly hatched larvae measured 1.52 ± 0.002 mm in total length (L) and carried a large yolk of 1.71 mm^3. The hatching rate of floating eggs ranged between 10.3% to 98.8%. At ambient water temperature and normal sea water of 28°C to 29°C and 34 ppt to 34.5 ppt respectively, incubation period was about eighteen to twenty hours.

Table 1 summarizes the results of the laviculture trials conducted in 1998 and 1999. In 1998, the survival rate ranged from 2.65% to 5.13% and larvae reached an average length of 24.5 ± 0.6 mm after fifty days of rearing. In 1999, the survival rate ranged from 19.03% to 53.92% and larvae reached an average length of 24.8 ± 0.4 mm after fifty days of rearing. The survival rates in the 1999 trials were significantly higher than in the1988 trials. Experience from the 1988 trials identified the following four main factors contributing to larval mortality: floating death, entanglement by larval spines, nutritional deficiency and infection of Viral Nervous Necrosis (VNN). Cannibalism was not the main factor of mortality in this species. In the 1999 trials, countermeasures were taken to minimize mortality. The countermeasures are described below.

Table 1: Rearing trials of larval *Cromileptes altivelis,* fifty days after hatching

Trial No	Water Volume (m^3)	Number Stocked	Number of survival	Survival (%)	Average total length (mm)
1998					
1	10	100,000	2,880	2.88	25.3
2	10	100,000	3,204	3.20	24.3
3	10	100,000	2,630	2.63	24.9
4	10	100,000	5,131	5.13	24.3
5	10	125,000	3,310	2.65	23.6
6	10	142,000	5,545	3.90	24.8
Average				3.39	24.5
SE				0.97	0.6
1999					
7	4	20,000	8,806	19.03	25.2
8	4	20,000	4,473	22.37	24.9
9	4	20,000	7,182	35.91	24.7
10	4	35,000	11,407	32.57	25.1
11	10	54,000	29,100	53.90	24.7
12	10	70,000	25,020	35.74	24.1
Average				33.25	24.8
SE				12.33	0.4

SE = standard error of the mean

In 1988, high mortality (more than 40%) of larvae occurred during the initial two to five days after hatching (DAH). The mortality was due to floating death. Larvae between one and five DAH are easily trapped by surface tension. Once trapped by the water surface, larvae cannot escape and eventually die. Trapped larvae may become stressed and secrete a sticky mucus. The mucus from trapped larvae will accelerate the trapping of other larvae, which leads to high mortality at early larval stages. These occurrences were frequently observed in the 1988 larviculture trials. In order to prevent mortality, measures were taken in 1999: spreading fish or squid oil on the water surface, providing strong aeration before larval mouth opening and maintaining green water color.

During the early stage of larviculture, the larvae were positively phototactic and aggregated in the bright areas of the larval rearing tanks whenever the algal cell densities decreased in the tank due to active feeding of rotifers on *Nannochloropsis* sp. Maintenance of alga densities of 300-400 x 10^3 cell/ml was effective in reducing the phototactic behavior and dispersing the larvae in the culture tank.

The long dorsal and ventral spine had a distinct appearance by day ten and eleven (Kumagai et. al. 1998). As growth proceeded, along with the dorsal and ventral spines many spinelets appeared on the anterior and posterior margins. The melanophores also expanded and darkened (Sugama et al. 1998). Metamorphoses initiated from day thirty-five onward, and all larvae completed metamorphoses by day fifty (Kumagai et al. 1998, Matsuda et al.1998).

Larvae between ten and twenty-five DAH have elongated dorsal and two pelvic spines. At this stage, many larvae died due to entanglement with the spines, especially when the larvae swam to the water surface at certain places of the tank because of light intensity. The larvae aggregated and clustered together, then died. To prevent the larval aggregation the number of air stones was increased and they were placed close to the tank walls, the water color was kept green, and light intensity was controlled by artificial lighting to disperse the larvae in the culture tank.

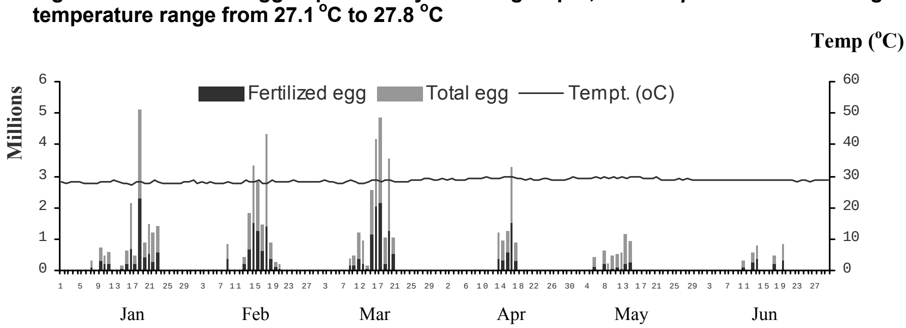
The larvae were ingesting SS-type rotifers on day three onward. The active feeding of larvae on S-type rotifers increased from five DAH and therefore increased rotifer densities in the larval rearing tanks to cope with the larval feeding. At seven DAH when the larvae reached around 3 mm TL, they were supposed to engulf air for their swim bladder inflation. Failure in air gulping may cause malformation of the vertebrae column and in some cases the larval died. Cleaning the oil film on the water surface at six DAH was effective in decreasing the incidence of malformation.

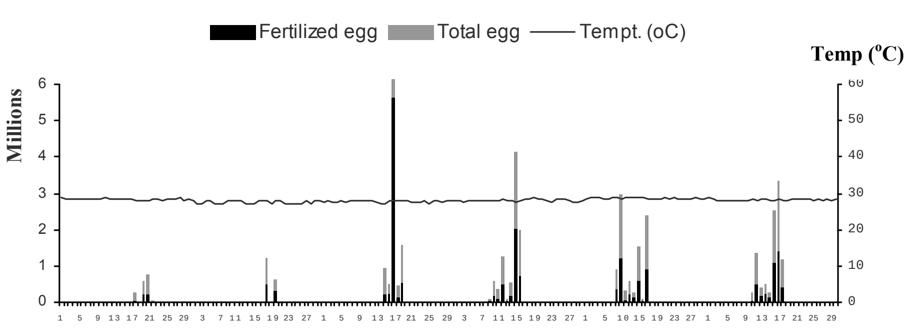
Gradual larval mortality was observed after twenty-five DAH. This was suspected to be due to nutritional deficiency. To prevent this problem, the rotifer and artemia as feed were enriched by commercial products and larvae were weaned onto a commercial compound feed as an artificial diet (Figure1).

When VNN breaks out at the early stage of larval rearing (before twenty DAH), in most cases, a total mortality occurred. There is no special treatment method for VNN at present. One measure that should be taken is to use VNN free eggs for laviculture of this fish (Kusharyani et al. 1999). Each broodstock that has been used to produce eggs was examined for VNN virus through checking the gonad and sperm by Polymerase Chain Reaction (PCR) test. Only unaffected VNN broodstock were spawned in captivity. Similarly, newly hatched larvae were examined for VNN virus and only free VNN larvae were reared.

In summary, the barramundi cod, *Cromileptes altivelis* readily spawn in captivity without the use of hormones or other treatment. A rearing methodology is now available for the mass production of barramundi cod grouper larvae to juvenile stages with a survival rate greater than 30%. The technique developed in this study should assist with procurement of seed for establishment of a large scale fish culture enterprise.

Figure 2. Number of eggs spawned by mouse grouper, *Cromileptes altivelis* during 1999, water temperature range from 27.1 °C to 27.8 °C





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Review of Grouper Diseases and Health Management Strategies for Grouper and other Marine Finfish Diseases

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Abstract

Grouper has recently become one of the most important aquaculture and traded commodities in the Asia-Pacific region. The expanding trade in live grouper of different ages and stages (whether for aquaculture or for seafood restaurants) increases the risks of moving pathogens. The number of diseases affecting grouper has expanded steadily with expansion and intensification of grouper aquaculture. These include infectious (virus, bacteria and parasites) and non-infectious (environment, management, nutritional) diseases and a number of diseases yet undiagnosed or of unknown origin. Apart from some virus problems in Southeast Asia, very little is known about the impact of major diseases that may go beyond direct mortalities and production losses. They affect all levels of aquaculture activity and are profoundly felt by small-scale farmers who represent the backbone of many rural communities in Asian aquaculture. Their livelihoods are threatened through reduction in food availability, loss of income and employment, social upheaval and increased vulnerability.

Unless appropriate measures are implemented, major epidemics will continue to threaten the industry. It may cost more to contain them later. This paper presents available information on infectious and other diseases affecting grouper aquaculture in the Asia-Pacific region and current disease control practices. It also provides some recommended health management options, which may be applied or which can be further explored for attaining high health status to sustain grouper aquaculture.

Introduction

Grouper has recently become one of the most important aquaculture and trade commodities in the Asia-Pacific region. It is also an important fish in the livelihoods of small and large-scale coastal fish farmers. The intensified trade in live groupers resulted from a number of recent developments: increased consumption and high cultural and social preference for this fish; the growing live seafood market and restaurants in China PR, Hong Kong China, Chinese Taipei and Singapore (and to a lesser extent in most economies of the Asia-Pacific region); and intensified aquaculture due to high economic returns. Groupers are now considered a high-value species with a high potential for contributing to the economic development of these countries. Hong Kong, China and China PR are the main markets for live grouper, other smaller markets include Chinese Taipei and Singapore. The main suppliers of live grouper to

Hong Kong, China are Indonesia, Philippines, Malaysia, Thailand, Vietnam and Australia, with a large portion eventually shipped to China PR (Pawiro 1999).

This paper reviews the reported diseases, which affect grouper belonging to the genera *Epinephelus, Cromileptes* and *Plectropomus* (Table 1). It also covers health management strategies available for grouper and other marine finfish. The review of health management strategies is based on published reports and the scientific literature available to the authors at the time of writing. The paper provides some additional recommendations on dealing with trans-boundary aquatic animal diseases. It also includes an update on APEC Fisheries Working Group project APEC/FWG 02/2000 "Development of a Regional Research Program on Grouper Virus Transmission and Vaccine Development".

Impacts of Trans-boundary Diseases

Trans-boundary diseases are epidemic diseases that are highly contagious or transmissible and have the potential for very rapid spread across national borders. These diseases cause serious socio-economic and possibly public health consequences (Baldock 2001).

Some examples of recent trans-boundary aquatic animal diseases which had major social and economic impacts in the Asia-Pacific region are the epizootic ulcerative syndrome or EUS of freshwater and brackish water fish, and the viral diseases of shrimp (white spot syndrome virus, yellow head virus and taura syndrome virus). The impact of these diseases goes beyond direct mortalities and production losses and affects all levels of aquaculture activity. Small-scale farmers who represent the backbone of many rural communities in Asian aquaculture also profoundly feel them. Their livelihoods are threatened by reduction in food availability, loss of income and employment, social upheaval and increased vulnerability. In large-scale aquaculture, the impact on investor confidence is considerable, with a further impact on the employment and income of rural communities where such operations exist. There is also increasing concern regarding newly emerging diseases facing the Asian region. These include marine finfish mortalities due to viral diseases among seabass and groupers; epizootics in shellfish (scallop mortalities in China, pearl oyster mortalities in Japan, Indonesia, Philippines); and the spawner mortality virus (SMV) in shrimp.

Among grouper diseases, a disease of viral origin, a monogenean parasite, and a variety of other parasites were reported to be associated with importing of live fish. *Neobenedenia girellae*, one of the most commonly reported parasites of grouper, has been introduced to Japan by imports of amberjack fry from Hainan, China and Hong Kong (Ogawa *et al.* 1995a). The other disease of viral origin, 'red grouper reovirus', was reported by Chew-Lim *et al.* (1992) in red grouper (*Plectropomus maculatus*) imported from Indonesia for culture in Singapore. Earlier reports by Leong and Wong (1990) showed that grouper imported from Thailand and Philippines for cage culture in Malaysia were heavily infected with a wide variety of parasites. Chong and Chao (1986) reported that import mortalities are the single most important source of loss to local fish farmers in Singapore.

Table 1: Grouper species: scientific names and common names included in this review.

Scientific Name	Common Name[1]	Country[2]
1. Epinephelus akaara	Hong Kong grouper (FB 96, FAO) Red-spotted grouper (Hawaii, FB 96) Kijihata (Japan, FB 96) Red grouper (Hong Kong, FB 96)	China PR, Japan
2. E. awoara	Yellow grouper (FB 96, FAO) Green-spotted grouper (China, Chen 1995) Aohata (Japan, FB 96)	China PR
3. E. bontoides	Pale margin grouper (FB 96)	Indonesia
4. E. coioides = E. suillus (synonym)	Orange-spotted grouper (FB 96) Estuary grouper (Fish Base 96) Estuary cod (Australia, FB 96) Chi hou (Singapore, Malay/Indonesia, FB 96) Estuary grouper (Hong Kong, FB 96) Chairomaruhata (Japanese)	Indonesia, Philippines, Thailand
5. *E. chlorrostigma*	(Hua *et al.* 1994)	China
6. E. cyanopodus	Speckled blue grouper (FB 96)	Japan
7. E. fuscoguttatus	Brown-marbled grouper(FB 96, FAO) Flowery cod (Australia, FB 96)) Tiger grouper (Malaysia)	Indonesia, Malaysia
8. E. malabaricus	Malabar grouper (FB 96)	Indonesia
	Brown-spotted grouper (Thailand, Danayadol *et al.* 1996)	Thailand
9. E. moara	Kue (Japanese, FB 96)	Japan
	Kelp grouper (Nakai et al. 1994, Muroga 1995)	
10. E. salmoides	(Ong 1988)	Malaysia
11. E. septemfasciatus	Convict grouper (FB 96) Sevenband grouper (Japan, Fukuda *et al.* 1996) Mahata (Japanese, FB 96)	Japan Korea RO
12. E. tauvina	Greasy grouper (FB 96)	Malaysia, Philippines Singapore
	Brown-spotted grouper (Malaysia, Chua *et al.* 1994)	
	Estuarine grouper (Malaysia, Nash *et al.* 1987)	
13. Epinephelus spp.		Philippines, Taipei China, Myanmar
14. Cromileptes altivelis	Humpback grouper (FB 96) Barramundi cod (Australia, FB 96)	Indonesia
15. Plectropomus leopardus	Leopard coral grouper (FB 96, FAO) Common coral trout (Australia, FB96)	Indonesia
16. Plectropomus maculatus	Spotted coral grouper (Lau and Li, 2000)	Singapore
17. Plectropomus spp.	Red grouper (Chua *et al.* 1993)	Singapore

Statistics on economic impact of marine finfish diseases including diseases of groupers are scarce. In Japan, losses due to marine fish disease amount to approximately US$ 114.4 M (1992). In Thailand, losses in marine cage-cultured seabass and grouper due

[1] The common names indicated in this Table were mainly taken from ICLARM's Fish Base 96 (FB 96) or by another reference in some cases.
[2] Refer to the countries where reports of diseases are indicated in the other Tables

to diseases were about US$ 1.9 M in 1989. In Malaysia, vibriosis in sea-caged farms resulted in losses equivalent to RM 20 million in 1990 (more than US$.5 million). In a survey of the disease situation of marine fish in Singapore, Chua *et al.* (1993) estimated losses due to diseases at two farms at Singapore$ 126, 800 and S$ 233, 700.

In a survey on the impact of fish health problems on rural small-scale farmers involved in grouper culture in the Philippines, 75% of respondents experienced reduction in income due to fish health and disease problems, while 19.44% incurred increased household debt, particularly those who borrowed capital for investment (Somga *et al.* 2001q). In Thailand where finfish cage culture of seabass and grouper is mostly comprised of small farms (one to five cages), more than 80% of farmers reported losses ranging from 30% to 50% due to fish diseases (Kanchanakhan *et al.* 2001).

The expanding trade in live grouper of different ages and stages for aquaculture or for the seafood restaurants without appropriate quarantine and health considerations increases the risks of moving pathogens that may come along with the movement of host fish. Unless measures are implemented, major epidemics continue to threaten the region. It may cost more to contain them and would cast doubt on the sustainability of grouper aquaculture.

Grouper Diseases in Asian Aquaculture

Arthur and Ogawa (1996) overview of disease problems in the culture of marine finfishes in East and Southeast Asia identified the principal diseases (Box 1) in grouper (primarily *Epinephelus* spp.) cultured in Southeast Asia.

Box 1 (Arthur and Ogawa, 1996)

Environmental:	pollution, toxic plankton blooms
Management:	acclimatization/adaptation mortalities (juveniles); handling mortalities (juveniles and grow-out); transport mortalities (juveniles)
Nutritional:	spinal curvature
Viruses:	golden eye disease; Red grouper reovirus; Sleepy grouper disease (iridovirus); Spinning grouper disease (picorna-like virus)
Bacteria:	Red boil disease, streptococcosis (*Streptococcus* sp.); Vibriosis, hemorrhagic septicaemia (*V. alginolyticus, V. parahaemolyticus*)
Parasites:	Protozoa (*Amyloodinium,* so., *Brooklynella* sp., *Cryptocaryon irritans*, *Trichodina* sp.) Monogenea (*Benedenia* sp., *Megalocotyloides epinepheli*, *Pseudorhabdosynochus epinepheli*)
Fungi:	*Ichthyophonus* sp.

Diseases of unknown aetiology: popeye, blindness, swimbladder syndrome

The following section (updated from Arthur and Ogawa, 1996) presents information on infectious diseases (viral, bacterial and parasitic) and diseases which are either undiagnosed or of unknown origin but of increasing importance.

Viral Diseases

The first grouper viral disease was reported by Mori *et al.* (1991) as a disease similar to Viral Nervous Necrosis (VNN) affecting larval and juvenile stages of *E. akaara* in Japan and which caused 80% mortality. In 1994, Nakai et al. reported hatchery mass mortalities among kelp grouper*, E. moara*. This time it was diagnosed as VNN. Since

1995, reports of viral infection (mainly of Nodaviruses) in Singapore, Thailand, Japan and Korea have been published. Chua *et al.* (1995) reported a 'spinning grouper disease' which caused heavy mortalities among *E. tauvina* fry for two weeks in 1991 in Singapore. There was no visible external or internal lesions but affected fry exhibited loss of equilibrium, uncoordinated and weak swimming movements, swimming in circles and in some cases splasticlateral flexure of the body. Chew-Lim *et al.* (1998) isolated a nodavirus comparable to the striped jack nervous necrosis virus (SJNNV). Nodavirus was collected on *E. tauvina* juvenile samples (2-4 cm). It caused high mortalities during the period from 1986 to 1991 in Singapore. In Japan, Fukuda *et al.* (1996) reported mortalities of sevenband grouper *E. septemfasciatus*, with body weights ranging from 170 g to 1850 g during the summer season (July to October) in 1993-1994 when water temperature was between 25°C and 28°C. Affected fish exhibited upside down swimming, inflation of the swim bladder and degeneration of nervous tissues. The disease was diagnosed as VNN. Sohn and Park (1998) reported VNN among sevenband grouper in Korea. The disease occurred during the summer season, with mortalities reaching more than 80% within a few weeks. Clinical signs included anorexia, dark coloration, spiral swimming behaviour and vertebral deformity. In Thailand, 'paralytic syndrome' caused by VNN was reported by Danayadol *et al.* (1995) among 2.5 to 15.0 cm sized *E. malabaricus*, with mortality reaching 100% in small fish and less than 20% in large fish. Clinical signs included lethargy, dark body coloration, loss of appetite and corkscrew swimming.

The second viral disease, 'sleepy grouper disease', caused by Iridovirus was first reported by Chua *et al.* (1994). It occurred in early grow-out and market sized *E. tauvina* in Singapore in 1992. In Chinese Taipei, an outbreak occurred in 1995 among *Epinephelus* spp. Chou *et al.* (1998) identified the causative agent as Grouper Iridovirus of Taiwan (TGIV). In 1999, Kasornchandra (1999) and Khongpradit *et al.* (1999) reported two types of Iridoviruses, 'GIV-1' and 'GIV-2' or blister disease, which affected unspecified grouper fry and fingerlings and *E. coioides*, respectively.

Other diseases of viral origin include the following:

- red grouper reovirus disease, which occurred in red grouper *(P. maculatus*) imported from Indonesia for culture in Singapore (Chew-Lim *et al.*, 1992)
- the golden-eye disease (astro-like virus) which caused 90% mortality among *E. tauvina* in Sumatra (see Arthur and Ogawa 1996)
- lymphocystis disease virus of *E. fuscoguttatus* in Malaysia (Oseko *et al.* 1999), and herpes virus of *E. awoara* juveniles in China (Chen 1996)

It appears that there are several viruses affecting several species of cultured grouper:

(a) nodavirus – Viral Nervous Necrosis or VNN
(b) iridovirus – GIV-1, GIV-2 and TGIV
(c) lymphocystis
(d) Herpes virus
(e) golden eye disease (astro-like virus), and
(f) red grouper reovirus disease (see Table 2)

Table 2: Viral infection of grouper cultured in Asia

Disease Pathogen	Host Stage Affected	Signs and Behaviour Other Characteristics	Country	Reference
NODAVIRUSES				
Similar to VNN	*E. akaara* larval juvenile	Larval stage: 7-8 mm TL (14 day old) Heavy mortality at 9-10 mm and continued until 20 mm Juveniles: 26-39 mm Rearing temperature for both cases: 25-27°C 80% mortality Listless swimming near surface of water, abrupt whirling and sinking to bottom	Japan	Mori *et al.* 1991
VNN	*E. moara*	Hatchery mass mortality Retina and brain of diseased fish were necrotic and vacuoles formed after degeneration of dead cells Viral particles with diameter of 28 nm densely present in the cytoplasm of neuron cells in these tissues.	Japan	Nakai *et al.* 1994; Muroga 1995
'Spinning grouper disease' (suspected Nodavirus)	*E. tauvina*	2 weeks in 1991 among fry Heaviest mortalities 7-9 days after onset of clinical signs Loss of equilibrium, uncoordinated and weak swimming movements, swimming in circles and in some cases splastic lateral flexure of the body No visible external or internal lesion	Singapore (similar disease also reported in this paper from Malaysia and Philippines)	Chua *et al.* 1995
Paralytic syndrome VNN	*E. malabaricus*	2.5 to 15.0 cm in body length Lethargy, dark body coloration, loss of appetite, corkscrew swimming Water temperature: 28 to 30° C Mortality in small sized fish (2.5 to 7.5 cm) reached 100%, while large fish (over 15 cm) less than 20% Vacuolation and virus-like particles observed in brain and eyes	Thailand	Danayadol *et al.* 1995
VNN	*E. septemfasciatus* (Sevenband grouper) 170 to 1850 g	Summer season (July to October 1993/1994) Water temperature: 25-28 °C Upside down swimming behaviour, inflation of swimbladder, degeneration of nervous tissues	Japan	Fukuda *et al.* 1996
Nodavirus Viral Nervous Necrosis (VNN)	*E. septemfasciatus* (Sevenband grouper) Adults and larval stages	During summer season Mortality over 80% within a few weeks Anorexia, dark coloration, spiral swimming behaviour and vertebral deformity	Korea RO	Sohn and Park 1998
Nodavirus comparable to Striped Jack Nervous Necrosis Virus (SJNNV)	*E. tauvina* juveniles	1986 to 1991 samples High mortalities in 2-4 cm juveniles	Singapore	Chew-Lim *et al.* 1998

Table 2: Viral infection of grouper cultured in Asia (continued)

Disease Pathogen	Host Stage Affected	Signs and Behaviour Other Characteristics	Country	Reference
IRIDOVIRUSES				
Iridovirus 'Sleepy Grouper Disease'	*E. tauvina* Early grow out and market-sized	April to August 1992 50% mortality among early grow-out (100-200 g) and market-sized (2-4 kg) Affected fish generally lacked external lesion, however, were extremely lethargic and did not respond to physical stimulation, inappetence solitary and either hung at the water surface or remained at the net bottom Deaths occurred at night time or early hours of the morning	Singapore	Chua *et al.* 1994
Iridovirus Grouper Iridovirus of Taiwan (TGIV)	*Epinephelus sp.*	Since 1992 Outbreak in 1995, 60% mortality Anemia, Swimming in circles	Chinese Taipei	Chou *et al.* 1998
Iridovirus 'GIV-1'	Unspecified fry and fingerling of grouper	Reduced feed consumption, lethargy and appearance of darkening on the fish body especially on the postal end including fin Moribund fish float up to the water surface, sink down to bottom and die 30-50% of affected fish die Icosahedral virus whose size ranges from 140-160 nm in diameter	Thailand	Kasornchandra 1999
Iridovirus 'GIV-2' 'Blister Disease'	*E. coioides*	Appearance of whitish blisters on the body and fins Highly localised severe inflammation of the epidermal and dermal layer Dermis was necrotized, containing exudation and hemmorrhagic inflitration at the area of intact layer Presence of icosahedral to round-shaped virions with a diameter of 180-200 nm in infected liver, spleen, kidney and lesions	Thailand	Khongpradit *et al.* 1999
REOVIRUS				
Red grouper Reovirus	*Plectropomus maculatus*	Inappetence and lethargy, followed by death 2-3 days later Virus isolated from spleen: ribonucleic acid, ether resistant, and able to tolerate heat treatment up to 56 C. Electron microscopy showed a reovirus, diameter of 67-72 nm, double-membrane capsid and no envelope Similar to grass carp virus	Imported from Indonesia for culture in Singapore	Chew-Lim *et al.* 1992
ASTRO-LIKE VIRUS				
Golden eye disease (astro-like virus)	*E. tauvina*	90% mortality Anemia leading to suffocation of affected fish	Sumatra	cited in Arthur and Ogawa 1996 as personal comunication with Leigh Owens (James Cook University)

Table 2: Viral infection of grouper cultured in Asia (continued)

Disease Pathogen	Host Stage Affected	Signs and Behaviour Other Characteristics	Country	Reference
LYMPHOCYSTIS				
Lymphocystis	*E. fuscoguttatus* Juveniles (6.3-21.9 g BW)	May 1999 Many nodules on snout, lower jaws, fins and skin Abnormally dark colored patches of skin with numerous nodules superimposed with cream-colored particles	Malaysia	Oseko *et al.* 1999
HERPES VIRUS				
Herpes virus	*E. awoara* Juveniles	Infected fish become paralyzed and exhausted and die at botttom of cage	China	Chen 1996

Bacterial Diseases

A range of bacterial diseases has also been reported, including *Vibrio* spp., *Pseudomonas* sp, *Pasteurella piscicida* and *Flexibacter* sp. (Table 3). Bacteriosis caused by *Pseudomonas* sp. among *E. tauvina* cultured in Malaysia was first reported by Nash et al. (1987), where all age groups were affected during an outbreak in November/December to February/March in 1982-1986. Mortalities ranged from 20% to 60%. Affected fish showed extensive haemorrhagic erosions and ulcerations of the skin, fins and tail. Vibriosis was reported among *E. suillus* (= *E. coioides*) broodstock in cages and tanks in the Philippines (Lavilla-Pitogo *et al.* 1992), *E. tauvina* in Kuwait (Saeed 1995), *E. malabaricus* in Thailand (Chinabut 1996) and *E. malabaricus* and *Epinephelus* sp in Malaysia (Wong and Leong 1990, Palanisamy 1999). Another bacterial infection, 'red boil disease' caused by *Flexibacter* sp. among *E. malabaricus* in Thailand was reported by Danayadol *et al.* 1996. In Japan, pasteurellosis caused by *Pasteurella piscicida* is a problem among juvenile red spotted grouper in hatcheries (Muroga 1995).

Parasitic Diseases

A large number of parasites (Table 4) are reported; some cause significant problems for grouper aquaculture. The parasites (protozoans, myxozoans, microsporans, monogeneans, trematodes, crustaceans, nematodes, cestodes, acanthocephalans and hirudineans) include external (skin and gills) and internal parasites. Parasite fauna of healthy and diseased *E. malabaricus* in Malaysia, Thailand and Philippines was most extensively studied by Leong and Wong (1988 and 1990). Infection with *Cryptocaryon irritans*, monogenean infection by *Benedenia* sp., *N. girellae, Diplectanum and P. epinepheli* and leech infection seem to cause serious problems to grouper. *N. girellae* has been well studied and information on its life-cycle, reproduction, immunity, susceptible hosts and treatment is available (see Bondad-Reantaso *et al.*, 1995a, 1995b and others cited in this report). One characteristic of this monogenean is low host specificity, which is rare for monogeneans. It has spread to at least twelve other cultured species in Japan including three species of grouper. Benedeniid monogeneans are particularly dangerous in net cage culture systems, where their eggs entangle the net meshing with elongated appendages, which makes re-infection much easier for the parasites (Ogawa, 1996). *Cryptocaryon irritans* is also a well-studied parasite. There is information on its life-cycle, pathology treatment and other biological characteristics such as temperature and salinity tolerance (Jee *et al.* 1997, Yuasa *et al.* 1999).

There were several reports indicating mixed parasitic/bacterial infection. These include reports of Lavilla-Pitogo *et al.* (1992), who reported that fish suffering from vibriosis also harbored a significant number of monogenean parasites causing gill lesions, and the results of the survey conducted by Chua *et al.* 1993.

Studies on the parasite fauna of groupers are useful in making import risk assessments and should be encouraged.

Table 3: Bacterial diseases of grouper cultured in Asia

Disease Bacteria Isolated	Species Stage Affected	Signs Behaviour Other characteristics	Country	Reference
Bacteriosis *Pseudomonas* sp.	*E. tauvina*	During northeast monsoon season (November/December to February/March)1982-1986 20-60% mortalities in raft cage cultured grouper All age groups affected Extensive haemorrhagic erosions and ulcerations of the skin, fins and tail	Malaysia	Nash *et al.* 1987
Pasteurella piscicida	*E. akaara*	Juveniles in hatcheries	Japan	Muroga 1995
'Red boil disease' *Flexibacter* sp.	*E. malabaricus*		Thailand	Danayadol *et al.* 1996
Vibrio spp.	*E. salmoides*	Swimming near water surface, loss of balance and anorexia Dark body color with external haemorrhagic lesions on body Fin and tail rot common,, eye lens sometimes turned opaque	Malaysia	Ong 1988
	E. malabaricus		Malaysia	Wong and Leong 1990
	E. suillus	Broodstock in cages and tanks Fish also harbored significant numbers of monogenean parasites causing gill lesions	Philippines	Lavilla-Pitogo *et al.* 1992
	Epinephelus sp.		Malaysia	Palanisamy *et al.* 1999
Vibrio harveyi	*E. tauvina*		Kuwait	Saeed 1995
Vibrio parahaemolyticus	*E. malabaricus*		Thailand	Chinabut 1996

Other Diseases

Other diseases (Table 5) are associated with import mortalities, handling and transportation mortalities and include diseases of undiagnosed (white spots, mortalities without clinical signs) or unknown aetiology (swim bladder syndrome, pop-eye or exopthalmia).

Among these diseases, the swim bladder syndrome has been extensively studied by Hua *et al.* (1994), who postulated that the syndrome closely resembled lipid peroxidase intoxication occurring on fish fed with putrefied trash fish or pelleted diets containing rancid lipid components. They indicated that although a virus was not isolated, their research was not sufficient to rule out the possibility of virus infection. This syndrome has been observed among *E. coioides, E. tauvina and E. akaara* in Singapore, Malaysia and China (Chong and Chao 1986, Leong 1994, Hua *et al.* 1994).

Table 4: Parasites reported from grouper cultured in Asia

Parasite Species	Host	Country	Reference
PROTOZOA			
Brooklynella sp.	*Epinephelus* sp.	China	Chen 1996
Cryptobia sp.	*Epinephelus* sp.	China	Chen 1996
Cryptocaryon irritans	*E. bontoides*	Indonesia	Koesharyani *et al.* 1999a, 1998
	E. coioides	Indonesia	Koesharyani *et al.* 1999a, 1998
	E. malabaricus	Indonesia	Koesharyani *et al.* 1999a, 1998
		Thailand	Chinabut 1996, Ruangpan and Tubkaew 1993, Danayadol 1999; Leong and Wong 1990
		Malaysia	Leong and Wong 1988; Leong and Wong 1990
	Epinephelus sp.	China	Chen 1996
	C. altivelis	Indonesia	Koesharyani *et al.* 1999a, 1988; Yuasa *et al.* 1999
	E. tauvina	Kuwait	Rasheed 1989
Riboscyphidia sp.	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999b
Scyphidia sp.	*E. malabaricus*	Thailand	Chinabut 1996
Trichodina sp.	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999b
	E. bontoides	Indonesia	Koesharyani *et al.* 1999a
	E. malabaricus	Thailand	Chinabut 1996; Leong and Wong 1990
		Malaysia	Leong and Wong 1988, 1990
Vorticella sp.	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999b
MYXOZOA			
Myxosoma sp.	*Epinephelus* sp.	China	Chen 1996
Ceratomyxa sp.	*Epinephelus* sp.	China	Chen 1996
Sphaerospora sp.	*E. malabaricus*	Thailand	Chinabut 1996
MICROSPORA			
Pleistophora sp.	*Epinephelus* sp.	China	Chen 1996
MONOGENEA			
Benedenia sp.	*E. malabaricus*	Indonesia	Koesharyani *et al.* 1999a, 1998
		Thailand	Chinabut 1996
	Epinephelus spp.	Myanmar	Si Si Hla Bu 1999
	E. tauvina	Kuwait	Al-Marzouq and Al-Rifae 1994
		Singapore	Chua *et al.* 1993
B. epinepheli	*E. akaara*	Japan	Ogawa *et al.* 1995b
	E. moara	Japan	Ogawa *et al.* 1995b
	E. septemfasciatus	Japan	Ogawa *et al.* 1995b
Cycloplectanum epinepheli	*E. malabaricus*	Thailand	Chinabut 1996
Dactylogyrus sp.	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999b
Dactylogyrus spp.	*E. malabaricus*	Thailand	Ruangpan and Tubkaew 1993, Danayadol 1999
Gyrodactylus sp.	*E. malabaricus*	Thailand	Chinabut 1996
Haliotrema sp.	*C. altivelis*	Indonesia	Koesharyani *et al.* 1999a, 1998
Neobenedenia girellae	*E. akaara*	Japan	Ogawa *et al.* 1995a
	E. bontoides	Indonesia	Koesharyani *et al.* 1999a, 1998
	E. cyanopodus	Japan	Ogawa *et al.* 1995b
	E. coioides	Indonesia	Koesharyani *et al.* 1999a, 1998
	E. malabaricus	Indonesia	Koesharyani *et al.* 1999a, 1998
	P. leopardus	Indonesia	Koesharyani *et al.* 1999a , 1998
	Epinephelus spp.	Myanmar	Si Si Hla Bu 1999

Table 4: Parasites reported from grouper cultured in Asia (continued)

Parasite Species	Host	Country	Reference
Megacotyloides epenepheli	*E. malabaricus* (wild)	Malaysia	Leong and Wong 1988, 1990
Megacotyloides sp.	*Epinephelus* spp.	Myanmar	Si Si Hla Bu 1999
Tareenia sp.	*Epinephelus* spp.	Myanmar	Si Si Hla Bu 1999
Diplectanum sp.	*Epinephelus* spp.	Myanmar	Si Si Hla Bu 1999
Pseudorhabdosynochus sp.	*C. altivelis*	Indonesia	Koesharyani *et al.* 1999a
	Epinephelus spp.	Myanmar	Si Si Hla Bu 1999
Pseudorhabdosynochus epinepheli	*E. malabaricus*	Malaysia	Leong and Wong 1988, 1990
		Thailand	Leong and Wong 1990
		Philippines	Leong and Wong 1990
F. Dactylogyridae	*E. coioides*	Philippines	Erazo-Pagador 1999
F. Diplectanidae	*E. coioides*	Philippines	Erazo-Pagador 1999
TREMATODA			
Allopodocotyle sp.	*E. tauvina*	Malaysia	Kolandasamy and Shaharom-Harrison 1999
Allopodocotyle serrani	*E. malabaricus* (wild)	Malaysia	Leong and Wong 1988
Cardicola sp.	*E. malabaricus*	Thailand	Chinabut 1996, Leong and Wong 1990
		Malaysia	Leong and Wong 1988
Ectenurus sp.		Malaysia	Leong and Wong 1988
Gonapodasmius sp.	*E. malabaricus*	Thailand	Chinabut 1996
Helicometrina nimia	*E. malabaricus*	Malaysia	Leong and Wong 1990
Lecithochirium neopacificum	*E. malabaricus*	Thailand	Chinabut 1996
		Malaysia	Leong and Wong 1988
		Philippines	Leong and Wong 1990
Pearsonellum sp.	*Epinephelus* spp.	Myanmar	SiSi Hla Bu 1999
Prosorhynchus pacificus	*E. malabaricus*	Thailand	Chinabut 1996, Leong and Wong 1990
		Malaysia	Leong and Wong 1988, 1990
		Philippines	Leong and Wong 1990
Prosorhynchus sp. C	*E. tauvina*	Malaysia	Kolandasamy and Shaharom-Harrison 1999
Prosorhynchus sp.	*Epinephelus* spp.	Myanmar	SiSi Hla Bu 1999
	E. malabaricus (wild)	Malaysia	Leong and Wong 1988
Pseudopecoeloides sp.	*E. malabaricus*	Thailand	Chinabut 1996
Pseudometadena celebesensis		Malaysia	Leong and Wong 1988
Stephanostomum sp.		Malaysia	Leong and Wong 1988
F. Didymozidae	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999a
	Epinephelus spp.	Myanmar	Si Si Hla Bu 1999
CRUSTACEA			
Caligus sp.	*C. altivelis*	Indonesia	Koesharyani *et al.* 1999a
	E. malabaricus	Thailand	Chinabut 1996
		Malaysia	Leong and Wong 1990
Ergasilus borneoensis	*E. malabaricus*	Malaysia	Leong and Wong 1988
Gnathia sp.	*E. malabaricus* (wild)	Thailand	Chinabut 1996
Lepeoptheirus sp.	*E. coioides*	Indonesia	Koesharyani *et al.* 1999a, 1998
	E. malabaricus	Indonesia	Koesharyani *et al.* 1999a, 1998
	E. fuscoguttatus	Indonesia	Koesharyani *et al.* 1999a, 1998
	P. leopardus	Indonesia	Koesharyani *et al.* 1999a, 1998
Thebius sp.	*E. malabaricus*	Thailand	Chinabut 1996
NEMATODA			
Contracaecum sp.	*E. malabaricus*	Malaysia	Leong and Wong 1988
Echinocephalus sp.	*E. malabaricus* (wild)	Malaysia	Leong and Wong 1988

Table 4: Parasites reported from grouper cultured in Asia (continued)

Parasite Species	Host	Country	Reference
Raphidascaris sp. (larva)	*E. malabaricus*	Thailand	Chinabut 1996, Leong and Wong 1990
		Malaysia	Leong and Wong 1990
		Philippines	Leong and Wong 1990
2 species (unspecified)	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999b
CESTODA			
Tetraphyllidae	*E. malabaricus*	Thailand	Chinabut 1996
		Malaysia	Leong and Wong 1988
Cestoda gen sp. (metacestode)	*E. malabaricus*	Thailand	Leong and Wong 1990
		Philippines	Leong and Wong 1990
ACANTHOCEPHALA			
Acanthocephalus sp.	*E. malabaricus*	Malaysia	Leong and Wong 1988, 1990
		Thailand	Leong and Wong 1990
HIRUDINEA			
Unidentified species	*E. coioides*	Philippines	Cruz-Lacierda *et al.* 1999a
	E. malabaricus	Thailand	Chinabut 1996
		Malaysia	Leong and Wong 1988
	Epinephelus sp.	Philippines	Somga *et al.* 2001

Table 5: Grouper diseases of undiagnosed or unknown origin

Characteristics	Species Affected	Country	Reference
Swim Bladder Syndrome Over-inflation of the swim bladder Loss of buoyancy control: • Fish swimming in a head-down position near the surface • Fish swimming at the surface with their backs exposed • Fish swimming intermittently and erratically on their sides • Fish swimming upside down with visibly distended abdomens Widespread over s short period Less than 10% of fish affected No evidence of pathogen involvement	*E. coioides* 30 g to in excess of 10 kg fish	Singapore	Chong and Chao 1986
Swim Bladder Syndrome: inability to deflate hyperinflated swim bladder, lack external, internal lesions, death due to secondary causes (sunburn, Vibriosis), < 1 week course, 1-10% mortality rates, all year, worst in August/November CPE agent isolated from 2 outbreaks; possible viral agent affecting CNS	*E. tauvina* >200 g fish	Singapore	Chua *et al.* 1993
Swimbladder disease: Occurs within a short period of time particularly during intermonsoonal period	*E. tauvina*	Malaysia	Leong 1994
Grouper's Syndrome – also called Distensive disease, whirling disease, swim-bladder distention and swim-bladder syndrome Pathological features: General focal inflammation of the gills, gall bladder, swimbladder, kidney, GIT, heart, brain, spinal cord and ovary Oedematous change of the liver, kidney, spinal cord and stomach wall	*E. akaara* *E. chlorrostigma*	China	Hua *et al.* 1994

Table 5: Grouper diseases of undiagnosed or unknown origin (continued)

Characteristics	Species Affected	Country	Reference
"Bent Body Syndrome": spasticity of axial musculature, inability to maintain equilibrium; lack external and internal lesions, death due to secondary causes, 1-2 weeks course, 10-60% mortality, June-July and October- November; CPE agent from one fish; possible viral agent affecting CNS	*E. tauvina* All sizes, mainly 50-300 g fish	Singapore	Chua *et al.* 1993
Popeye (Exopthalmos)	*E. coioides*	Singapore	Chong and Chao 1986
"Red Ulcer Disease": Haemorrhagic ulcerations, tail/fin rot, 1 week course, 20-40% mortality rate, occurs all year round; parasitic and bacterial components on laboratory examination	*E. tauvina* All sizes affected	Singapore	Chua *et al.* 1993
White spots, eroded caudal fin, fin and tail rot Common during first 2 months of culture period Mortality may reach 70%	*Epinephelus* spp.	Philippines	Somga *et al.* 2001
Ulceration, red spots with tail and fin rot Common during grow-out stage Chronic and mortality may range from 10-35%	*Epinephelus* spp.	Philippines	Somga *et al.* 2001
Bulging eyeball, eye cataract Grow-out stage, mortalities less than 5%	*Epinephelus* spp.	Philippines	Somga *et al.* 2001
Ruptured gallbladder Acute with no external sign January and February	*Epinephelus* spp.	Philippines	Somga *et al.* 2001
Mortalities without gross signs Nursery and grow-out stages Acute and mortalities may reach 100%	*Epinephelus* spp.	Philippines	Somga *et al.* 2001
Mortalities without external/internal lesions Outbreak in 1990, 40% mortality	Red Grouper – *Plectropomus spp.* 100-200 g fish	Singapore	Chua *et al.* 1993

Health Management Options for Grouper and other Marine Finfish Diseases

Information on effective health management strategies for grouper and other marine finfish diseases is provided in a number of reports, workshop proceedings and scientific literature. The most noteworthy sources include:

- Common Diseases of Marine Foodfish, Fisheries Handbook No. 2 by YC Chong and TM Chao, Primary Production Department of Singapore (1986)
- Parasites and diseases of cultured marine finfishes in Southeast Asia by Leong Tak Seng of the Universiti Sains Malaysia (1994)
- Aquaculture Health Management Strategies for Marine Fishes, Proceedings of a Workshop in Honolulu, Hawaii, October 9-13, 1995 by KL Main and C Rosenfeld of The Oceanic Institute (1996), and
- Various scientific publications from Australia, China PR, Korea, Indonesia, Japan, Singapore, Malaysia, Philippines, Thailand and Chinese Taipei

The information presented in this section is based on the above sources. Additional health management options may be applicable or can be further explored for achieving better health in grouper aquaculture. These include:

- vaccination
- diagnostics and research

- epidemiological approach to disease control
- disease surveillance, monitoring and reporting
- responsible movement of live aquatic animals, and
- generic approaches to health management such as good farming practices, stress management, sanitation and hygienic measures, food and trash fish feed management, prevention of exotic diseases; management of infectious diseases and careful use of chemotherapeutants

Generic Approaches to Health Management

The objective of health management is to attain optimal production levels that will generate the highest possible profit to farmers, provide a stable supply of aquatic animal products and contribute to the national economy. This can be achieved through a programme that will prevent the occurrence of diseases, and if diseases do occur, reduce their incidence and severity, limit their spread, and prevent recurrence.

Good Farming Practices

A health management programme has several requirements and must cover all levels of aquaculture activity. At the production level, the requirements for a healthy environment include strong healthy seed and juveniles, proper nutrition, appropriate waste management, optimal water quality, and regular monitoring.

At the farm site level, good record keeping is essential. It should cover all aspects of farm operation. Farmers should be trained to understand the importance and value of such information in determining the course or nature of a disease outbreak, providing accurate and rapid diagnosis, and enabling sensible management decisions for intervention and control. Record keeping is crucial to aquaculture and can go a long way in supporting effective health and productivity management efforts. A good farm profile should contain the following information:

- Treatment administered
- Clinical signs (behaviour, appearance)
- Farm lay-out (inflow, outflow, connection of ponds)
- Animals cultured (species, numbers, origin, age classes)
- Yields (per pond, per cage, per farm, normal survival rates)
- Nutrition (live food, manufactured food, sources, feeding practices)
- Management practices (continuous stocking, closed operation, stocking densities)
- Mortality data (affected sites, cages, ponds along with approximate percentages and numbers), and
- Unusual events (abnormal weather changes, mortality above average, yield below average, land-use activity, run-off, spills, abnormal growth, spawning events)

In addition to regular record keeping, there should be a continuous monitoring and updating of information (new animals on farm, change of feed, new ponds connected, new farm upstream).

Stress Management

Stress is defined as the sum of biological reactions to any adverse stimulus, physical, mental or emotional, internal or external, that tends to disturb the organism's homeostasis. Should these compensating reactions be inadequate or inappropriate, they may lead to disorders (Dorland's Illustrated Medical Dictionary 1988). It is a condition that exists in practical fish farming. Sources of fish stress include overcrowding, poor water quality, fluctuating temperature, poor nutrition, bad management, careless handling, inappropriate transportation methods and procedures, adaptation to new environment; and stress of capture and handling in case of wild caught fish, and associated stress due to chemotherapy.

Chong and Chao (1986) reported that import mortalities are the most important cause of losses to local fish farmers in Singapore and noted a number of stress effects in newly imported fish. The effects included shock, physiological failure, off-feed, cannibalism and increased susceptibility to pathogens. They recommended some preventive measures as indicated in Box 2 below:

Box 2 (from Chong and Chao 1986)

Stress Effects	Recommended Preventative Measures
• Shock	Appropriate packing techniques
• Physiological failure	Proper acclimatization
• Off-feed	Stimulating feeding activity by using natural food in the beginning and including a few farmed conditioned fry/fingerling with the newly arrived stock to help familiarization with feeding regime
• Cannibalism	Separation of fish according to size; lowering the density and frequent feeding
• Increased susceptibility to pathogens	Sanitation of imported fry and fingerlings in order to: Reduce the parasite and bacterial load Seal open wound by antiseptic treatment Prevention of attack by pathogens in the new environment

In order to avoid mortalities due to opportunistic pathogens, handling and transportation stress and to ensure better survival of newly arrived stocks, Shariff and Arulampalam (1996) recommended the establishment of on-shore nursery facilities, which will give farmers the flexibility to introduce the fingerlings into the marine cages at the appropriate time after acclimatization.

A contingency for disease prevention is the prophylactic use of drugs, chemicals and biological treatments. As there will always be infectious agents in the environment, every effort should be made to prevent the progression of infection to a disease. Prophylactic procedures are useful during handling and transportation (seining, handling, shipping) particularly because fish are most vulnerable to injury, trauma or physiological stress during this time. Once the protective mucous layer of fish, scale or skin are damaged, fish become susceptible to air-borne, pathogenic bacteria, and other bacterial, fungal and parasitic infection. Some recommended prophylactic measures include:

- simple dip treatments with formalin (for ectoparasitic infections) or antibiotics (for injuries due to handling) before and after transportation, to ensure eradication of parasites and stress related to bacterial pathogens (Chong and Chao 1986), and
- transportation methods to avoid stress: reducing temperature fluctuations, using appropriate packing densities (not to exceed 129 g biomass per liter of water for a 12 hour period between packing and release); and use of anaesthesia.

> Anaesthesia can facilitate handling, loading and transportation by inducing quiescence (inactiveness), which in turn causes a reduction in excretion of ammonia and carbon dioxide in oxygen consumption, thus making pH values and quality of the transport water relatively fairly constant (Shariff and Arulampalam 1996)

Careful handling of animals is recommended including the use of non-abrasive materials and tools (knotless netting for scoop nets and cages). Fish should not be fed before handling (Chong and Chao 1986).

Maintaining a balanced environment through good farming management practices, avoiding stressful conditions, and practicing sanitary and hygienic measures (listed below) can minimize the occurrence of opportunistic pathogens.

Sanitation Measures and Hygienic Practices

Adherence to strict hygiene practices and sanitation standards can maintain fish health at production facilities and minimize diseases caused by infectious agents and preventing their spread via personnel and equipment. Some sanitation and hygiene practices include disinfection of hatchery equipment such as tanks, nets, boots and vehicles) and water supply (UV irradiation, ozone and micro-filtration, using good quality well water, sterilization of waste water from broodstock rearing tanks) (Sako, 1996). Farm level sanitary processes such as healing open wounds with antiseptics and antibiotics (acriflavine, nitrofurazone, formalin) and transshipment sanitization (addition of chemicals such as antibiotics and anaesthesia to facilitate transportation: 100 ppm formalin bath for one hour followed by 30 ppm nitrofurazone for four hours) had also been recommended (Chong and Chao 1986).

Cleaning and changing of net cages should be a regular activity. This practice reduced the incidence of monogenean infection in Japanese mariculture, where the long egg filaments produced by these parasites entangled in the net meshing and continued their life cycle. During the early years of mariculture in Japan (1970s and 1980s), the application of organic tin coating on the net meshing to prevent the growth of fouling organisms suppressed the propogation of monogenean infection through some unknown mechanism. When the use of the chemical was banned in 1996 because of fear of its accumulation in the host fish and some environmental concerns, the monogenean infection recurred (Ogawa 1996).

Bio-fouling is another consistent problem in cage culture systems. It decreases water exchange, reduces the supply of dissolved oxygen and removal of wastes products. The waste products may act as a reservoir for pathogenic microorganisms. Australia is currently developing anti-fouling polymers and coatings that release biodegradable anti-fouling compounds. Field trials suggested that the anti-fouling polymers prevented fouling for 260 days (Hodson *et al.* 1999). This new development can be further explored for use in grouper aquaculture.

Food and Trash Fish Feed Management

There have been reports that trash fish can be a source of infection (Yashiro *et al.* 1999), and that some diseases involving opportunistic pathogens result from deficient nutrition. Leong and Wong (1988) reported that the trematodes, cestodes, nematodes and acanthocephalans recovered from cultured grouper were most probably transmitted through trash fish. Proper nutrition is a vital component of any culture activity; it is essential to the health of animals. High quality trash fish in sufficient quantity with vitamin and mineral supplementation where possible is recommended (Leong 1994).

In Japan, food management is realized by (a) bath treatment of live food with nitrofuran derivatives, sodium nifurstyrenate to decrease the number of bacteria and (b) immunostimulant supplementation (beta-carotene) (Sako 1996).

Other recommended management practices for food and trash fish feed include keeping chilled trash fish for only up to three days; sorting to remove crabs, shrimp or unsuitable materials by washing with seawater using a pressurized water jet; and removal of uneaten or wasted trash fish from the system.

Prevention of Entry of Exotic Diseases and Risk Assessment

There are a number of other generic approaches to disease prevention, which may include stock movement controls, destruction of clinically sick animals, emergency harvest of apparently healthy animals, fallowing prior to stocking, sanitary measures (disinfection) and others. Although disinfection protocols and movement control can decrease the spread of disease by personnel, equipment and farmed animals, the agent may still remain in the water system. In most instances, by the time a diagnosis is confirmed, the agent would have been in the system for some time. The fate of any agent in the natural environment under natural conditions remains largely unknown. Once an agent has gained access to a water system, prevention of spread becomes very difficult. Prevention of entry of an infectious agent to the system is the preferred option. As long as the disease agent is absent from the system, a disease will not occur. Therefore, for exotic diseases the risks of introduction must be identified, assessed and managed.

Import Risk Analysis (IRA) is a transparent and science-based process of assessing disease risks associated with the importation of aquatic animals and their products (genetic material, feed stuff, biological products, pathological material). This process should be implemented in aquatic animal importation.

IRA is a fairly new concept in the region. Australia and New Zealand are perhaps the only countries conducting risk assessments for aquatic animal health imports. The Australian Quarantine and Inspection Service or AQIS recently published two documents on IRA: (a) The AQIS Import Risk Analysis Process and (b) Import Risk Analysis on Live Ornamental Finfish. They provide useful information in making IRA and describe the procedures being followed by the Australian government for importing plants, animals and their products.

Management of Infectious Diseases

Management of viral diseases requires a basic understanding of concepts regarding viruses. Most viruses are transmitted vertically (by eggs and fluids during spawning) and horizontally (host to host). Diagnosis of viral infection requires culture cell lines, electron microscopy and trained specialists. There are no therapeutic treatments for viral diseases. Viral infection, when it occurs, causes high mortalities, and may spread quickly if not contained. Therefore, an ideal approach would be prevention and management.

When an infection of viral origin exists, the following generic measures are recommended: destruction of infected stocks, emergency harvest, detection of carriers and finding ways to eliminate or limit the access of the carriers into the system.

In Japan, VNN infection of striped jack is controlled by the following prophylactic measures (Nakai *et al.* 1995):

- Suppression of virus multiplication in spawners by reducing stress factors
- Elimination of spawners and eggs positive for viral infection detected by PCR technique
- Disinfection of eggs and equipment with appropriate chemicals
- Rearing batches of larvae and juveniles in separate tanks supplied with disinfected water, and
- Separate rearing of larval and juveniles from broodstock to prevent water-borne infection caused by viruses shed from infected broodstock

Most bacterial infections are associated with stress. The agents (*Vibrio* spp.) are naturally present in the aquatic environment. Maintaining the highest possible quality of environment by applying proper chemotherapeutants (baths for external infections and medications for systemic infections), sanitation, disinfection, and prophylactic treatment during transportation and handling prevent the progression of an infection to a disease and can minimise the occurrence of stress-related bacterial infection.

Management of a parasitic infection depends on whether the infection is external or internal. A number of external parasites respond well to chemotherapy as indicated in Table 6. Other internal and tissue dwelling parasitic infections are much more difficult to control. There is no known treatment for internal parasites such as myxosporeans. Parasitic infections are threatening when present in large numbers. Poor environment and bad management such as poor water quality high usually worsen this condition, stocking densities, deficient nutrition, inappropriate waste management. Some of these parasites (myxosporeans and other flatworms) have complex life cycles. Information on their life cycles is required in order to determine appropriate control measures such as prevention of entry, chemotherapy, breaking the life cycle, eliminating or limiting access of other hosts involved in the life cycle. In addition, control of parasitic infection in open-water marine systems (such as nets and cages) is more difficult than control of infections in a freshwater system that is more controlled (Ogawa 1996).

Careful Use of Chemotherapeutants

Chemotherapy is widely used to control infectious parasitic, bacterial and fungal diseases. It has been used for control of parasitic and bacterial diseases of grouper as indicated in Table 6. However, experience demonstrates that there are problems in chemical treatment of fish diseases; in some cases the treatments can be harmful because of associated stress.

In Singapore, Chong and Chao (1986) reported some cases of drug overdose leading to fish death and other detrimental side effects. Formalin overdose results in severe gill damage. Ulcerative dermatitis develops with repeated treatment with nitrofurazone leading to fish death. Potassium permanganate use in marine conditions resulted in rapid reduction of MNO_4 to manganese oxide, which is toxic to fish.

Chemotherapeutants are only effective against some pathogen groups. Rather than providing a solution to health problems, they became palliative measures. Application of chemotherapeutants has created problems with toxicity, resistance, residues and possibly some public health and environmental consequences. Their efficacy under certain aquatic conditions (open water systems) remains questionable, and they can be costly. The use of chemicals in treating health problems has also been complicated by the misleading advice provided to the farmers by feed and chemical companies regarding the use of antibiotics and other therapeutic drugs. These companies are now coming under increased scrutiny. Other constraints to the use of chemotherapy include the lack of pharmakinetic data on drugs used, lack of standard procedures on use, safety issues, low number of licensed products, cost and time involved in registration and licensure requirements, and existing legislation, which ranges from very restrictive regulations to no regulation at all (OIE 1992).

Chemotherapy has certain value in preventing and controlling diseases in aquatic animals. It should be used in a judicious manner and the cost-benefit should be evaluated. Efforts should also be made to develop alternative methods of controlling diseases.

Table 6: Chemotherapeutants and other treatments reported for bacterial and parasitic diseases of grouper in the Asia-Pacific

Pathogen	Host Species	Treatment	Reference
Cryptocaryon irritans	*Cromileptes altivelis*	Transfer of infected fish to a *Cryptocaryon*-free tank to keep fish free from trophont infection; followed by another transfer 3-4 days when trophonts would have been shedded from the fish	Yuasa *et al.* 1999
	Estuarine or greasy grouper	Varied success using the following treatment: Formalin at 200 ppm for ½ to 1 hr, depending on fish's tolerance Formalin at 100 ppm + acriflavine10 ppm for 1 hr Formalin 25 ppm + malachite green 0.15 ppm for 12 hrs Nitrofurazone at 30 ppm for 12 hrs Malachite green at 0.5 ppm for ½ hr Methylene blue 0.1 ppm for ½ hr 100% freshwater for 1 hr (seabass and estuarine grouper only) Other recommended measures: Isolate sick fish from healthy fish Remove dead fish and terminally sick fish from net cages and destroy Treat as soon as symptoms develop	Chong and Chao 1986
	E. malabaricus	0.10-0.15 ppm malachite green mixed with 25 ppm formalin effective when used at an early stage	Danayadol 1999
Monogenean infection (e.g. *N. girellae, E. epinepheli, Benedenia* sp.)	*Cromileptes altivelis*	Bath treatment with 150 ppm hydrogen peroxide for 30 minutes for 7 consecutive days	Koesharyani *et al.* 1999b
Benedenia sp.	*E. tauvina*	Freshwater bath treatment for 15 minutes effective for dislodging parasites from gills and skin of broodstock	Al-Marzouq and Al-Rifae 1994
Dactylogyrus spp.	*E. malabaricus*	250 ppm formalin for 30 min for 3 days or continuous bath in 0.3 ppm Dipterex for 3 days	Danayadol 1999, Ruangpan and Tubkaew 1993

Table 6: Chemotherapeutants and other treatments reported for bacterial and parasitic diseases of grouper in the Asia-Pacific (continued)

Pathogen	Host Species	Treatment	Reference
Diplectanum sp. or other gill parasites	Unspecified marine fish	Formalin at 200 ppm for ½ to 1 hr with strong aeration, for 3 days Formalin at 25 ppm + malachite green at 0.15 ppm – overnight bath Acriflavine at 10 ppm bath for 1 hr or 100 ppm dip for 1 minute Dipterex at 20 ppm for 1 hr 100% freshwater for 1 hr (seabass and estuarine grouper only)	Chong and Chao 1986
Pseudohabdos ynchus-like infection	*E. coioides* fingerlings	250 ppm formalin for 1 hr or 2 hr freshwater treatment	Cruz-Lacierda *et al.* 1999b
Marine leech	*E. coioides* (spawner and juveniles)	Careful manual removal using wet cloth; 50 ppm formalin bath treatment for 1 hr with ample aeration for 3 consecutive days	Cruz-Lacierda *et al.* 1999b
Vibriosis *Vibrio* sp.	Groupers and seabass	Antibiotic treatment: Oxytetracycline: at 0.5 g per feed for 7 days Sulphonamides or potentiated sulphonamides: at 0.5 active ingredients per kg feed for 7 days Chloramphenicol: at 0.2 g per kg feed for 4 days If fish are not eating, bath treatment: Nitrofurazone: at 15 ppm for at least 4 hrs Sulfonamides at 50 ppm active ingredients for at least 4 hrs	Chong and Chao 1986
	E. suillus	Oxytetracycline administered by intramuscular injection for 5 days at a dose of 25 mg/kg body weight (for broodstock)	Lavilla-Pitogo *et al.* 1992

Aquatic Systems Health Management

The aquatic environment is a complex system that obscures the distinction between health, sub-optimal performance and disease. During epizootics, it is often difficult to determine the cause. It is usually the result of a series of linked events, which can be a combination of environmental factors, the health condition of stocks, the presence of an infectious agent or poor husbandry and management practices. A clear understanding of the relationship between the host, pathogen and environment is required. When addressing aquatic animal health problems, the environment with all biological processes should be considered a single entity.

Although in some cases disease control measures can be developed without information about the pathogens, knowledge of the disease organism, its natural history and impact on hosts greatly assists in the development of appropriate and cost-effective control procedures. The risks and impacts of a disease vary according to the prevailing conditions, therefore, the intervention for mitigating the problem may be different. An ideal option would be to use an aquatic systems health management approach. This approach involves (a) taking into consideration the environment, the host and the pathogen, (b) determining options (cull, treat, quarantine, disinfect) that are available for a specific disease situation, (c) performing a cost-benefit analysis and (d) proceeding with an appropriate health plan.

Diagnostics and Research

Conventional methods for pathogen screening and disease diagnosis include tissue culture and electron miscroscopy for viruses, isolation and serology for bacteria, necropsy using light microscopy for parasites, and histopathology for understanding the mechanism of disease. Considerable progress has been made in the development of immunoassays and DNA-based diagnostic methods such as fluorescent antibody tests (FAT), enzyme-linked immunosorbent assays (ELISA), radioimmunoassay (RIA), *in situ* hybridization (ISH), dot blot hybridization (DBH) and polymerase chain reaction (PCR) amplification techniques.

An expert consultation on "DNA-based Molecular Diagnostic Techniques: Research Needs for Standardization and Validation of the Detection of Aquatic Animal Pathogens and Diseases" was jointly organized by ACIAR, CSIRO, DFID, FAO and NACA and held in February 1999 in Bangkok, Thailand. The experts recognized the advantages of using DNA-based methods for pathogen detection. These technologies offer rapid results with potentially high sensitivity, specificity, and repeatability at relatively low cost. They have been adopted in shrimp culture, where the conventional histological procedures lack specificity and culture-based methods are not applicable. The consultation evaluated the use of DNA-based methods for important diseases and recommended development of a PCR based technology for viral encephalopathy and retinopathy or VER (Walker and Subasinghe 2000).

In Japan, PCR is used for detecting VNN infection in spawners and eggs of striped jack. In Korea, it is used for confirming VNN infection of sevenband grouper. Other countries such as Thailand, Chinese Taipei and Singapore use tissue culture methods and electron microscopy for diagnosis of viral infection. Rapid detection and diagnosis are required for important diseases such as those currently affecting grouper. Early detection of disease is important so that rational decisions for management, intervention or control can be made.

Research is fundamental to the development of health management programmes. It assists in understanding the disease mechanism and development of appropriate and cost-effective control procedures. Reference laboratories and collaborating centres are critically important to successful implementation of an aquatic animal health programme. Besides providing confirmatory diagnosis and facilitating research, the reference laboratories and collaborating centres standardize, validate and assist in the quality control of development and research programs.

Diagnostics and research should provide services to farmers and should be aimed at assisting farmers in solving aquatic animal problems and increasing farm productivity. To achieve this, the linkage between diagnosticians, farmers and researchers should be improved and strengthened.

Vaccination

Inducing and building resistance to diseases is another approach to controlling fish diseases. A wide range of methods exists including immunostimulants, adjuvants and vaccine carriers.

In developed countries, vaccination offers a good alternative to disease prevention and control. In Norway, bacterial diseases (vibriosis, coldwater vibriosis and furunculosis) are controlled through vaccination. In Japan, efforts are being undertaken to develop appropriate vaccines for major viral and bacterial diseases of finfishes. Commercial vaccines are available for red sea bream iridovirus (injection type), ayu and salmonid *Vibrio anguillarum* (immersion type), yellowtail *Lactococcus graviae* (*Enterococcus serioricida*) (feeding type), and they have been reported to be effective. The iridovirus vaccine is currently used only for red sea bream, but efforts are being made for the development of iridovirus vaccine for other fish species. It is expected that more vaccines will be available within the next five years (Ogawa, K, University of Tokyo, pers. comm.).

Leong and Fryer (1993) enumerated the required attributes and characteristics of an acceptable vaccine. These are:

- Long term protection
- Safe to the vaccinated animal
- Inexpensive to produce, license and cost effective
- Protection against all serotypic variants of the pathogen
- Protection at the time when the animal is most susceptible to the disease
- Adequate immunoprotection from the target disease under intensive rearing conditions found at commercial hatcheries and farms, and
- Easy administration, preferably orally or by immersion, and their application does not unduly disrupt the normal management scheme

Vaccines are specific for certain diseases. Their use requires considerable research on the target disease, involves careful planning, efficacy and cost evaluation. Vaccination against any disease is one of the fish health management options for disease prevention but it does not mean total exclusion of a particular disease.

Plumb (1995) evaluated the potential use of vaccines in Asian aquaculture and reported that there were only three vaccines used during that time: a multivalent vibrio (*Vibrio* spp.) preparation for shrimp, a *V. anguillarum* vaccine for fish, and, occasionally, a *Yersinia ruckeri* vaccine used for trout. Efforts on vaccine development in the Asia-Pacific region are very much at the experimental stage but Plumb (1995) indicated that there was great interest in their development and future use.

It is uncertain whether vaccination can offer protection against grouper diseases in Asian aquaculture as it has for other important diseases in developed countries. Vaccination needs to be evaluated in terms of efficacy, marketability and cost-benefit.

Epidemiological Approach to Disease Control

The concepts of epidemiology for use in aquatic animal disease control have recently been introduced in the region. Epidemiology uses population as the unit of study where a bi-directional approach (downward approach from the animal to organ, tissues, cell, molecule; and upward approach from the animal to pond, farm, province, country) to disease investigation provides insights into understanding the disease processes and allows the development of possible control strategies. Available studies on shrimp diseases in the Mekong Delta (Turnbull *et al.* 1999), Australia and Indonesia (Callinan *et al.* 1999) and EUS (Khan and Lilley 2001) using the concepts of epidemiology have lead to the identification of risk factors, their impact and interventions that are practically applicable. Although there are limitations on using epidemiology for aquatic animal pathogens (its inability to detect abnormal host carriers of significant pathogens especially those with low or unknown host-specificity), the approach shows good potential for improving health management and developing appropriate control measures.

Disease Surveillance, Monitoring and Reporting

Reporting aquatic animal disease is one of the major components of the FAO-NACA TCP/RAS/6714 in the Asia-Pacific region. The "Asia-Pacific Quarterly Aquatic Animal Disease Report" is produced in cooperation with the Office International des Epizooties (OIE) or World Animal Health Organization (Representation for Asia-Pacific) and contains a list of diseases including those listed by OIE and other diseases, which are deemed important to the region. The reporting system commenced in July 1998.

VER is listed under the category 'Other Significant Diseases'. This category refers to diseases of current or potential international significance in aquaculture, which have not been included in the list of diseases notifiable to the OIE because of their importance, geographical distribution, current knowledge or lack of approved diagnostic methods (OIE 1997). VER has several names, such as 'seabass viral encephalitis', 'viral nervous necrosis' or VNN, 'striped jack viral nervous necrosis' of SJVNN, 'fish viral encephalitis'. The status of this disease has been recently reviewed by Rodgers and Furones (1998), who have indicated that the causal agent is a member of the Nodavirus family, comprising a new group of strains different from the insect viruses (Nishizawa 1996).

In Australia, this virus is present on Australian barramundi, and reported in nine of fifteen months since the reporting system began (third quarter of 1998). The disease was also reported in Japan during July and September 1998, and in Taipei China in August 1998 and May 1999. Singapore and Thailand did not report this disease during the period but the disease is known to occur in these countries (in Singapore, the last major outbreak was reported in Nov-Dec. of 1997 among seabass fry). In the Philippines, the disease is suspected but not confirmed (NACA/FAO 1999a, NACA/FAO 1999b).

National disease surveillance and reporting systems to support regional and international disease reporting obligations are effective strategies for control and prevention of trans-boundary diseases. They have proven to be highly effective in terrestrial livestock disease control programs. In aquatic animal diseases, however, there are various factors that can make surveillance and reporting a more difficult endeavor. Aquaculture production involves a large number of species, a wide range of culture systems and management practices, and a variety of diseases (some with low or unknown host specificity and many with non-specific symptoms). Disease reports comprise the building blocks of an aquatic animal health information system that is invaluable for verification and validation of disease information generated at the country level, which in turn depicts the disease situation at the regional level. This information is required for instituting control and eradication programmes and effective early warning mechanisms to reduce the impact of new or exotic diseases.

Countries actively involved in the international trade of live groupers are urged to continuously participate in this reporting system, and strive to improve their reporting capabilities by using a higher level of surveillance. Countries with sound infrastructure and a demonstrated record of containing and controlling disease outbreaks will have a significant trade advantage. Surveillance, monitoring and reporting systems will serve as a value added label to aquaculture and fisheries products, because it will reflect the country's demonstrated ability of providing documented valid information on the health, origin and quality of their traded commodities.

Responsible Movement of Live Aquatic Animals

Trans-boundary aquatic animal diseases receive a lot of attention because of the high mortality and significant losses they can cause to national economies, their unpredicted and widespread nature, the speed of spreading among susceptible population, and the constant threat they pose to the livelihood of aqua-farmers. Experience with EUS and the viral diseases of shrimp demonstrated that trans-boundary aquatic animal diseases cross national or administrative borders, therefore, they need to be addressed on a regional basis through cooperation between countries and through harmonization of approaches. Effective cooperation at all levels is required.

Another major component of the FAO-NACA TCP/RAS/6714 is the development of "Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals" (FAO/NACA 2000). Representatives from twenty-one Asian governments, scientists and experts on aquatic animal health, as well as representatives from various national, regional and international agencies and organizations developed this document through a consultative review process. It contains a set of Guiding Principles on movement of living aquatic animals within and across national boundaries and proposes practical and effective strategies to minimize the risks of introduction, spread and establishment of trans-boundary aquatic animal diseases. The document contains technical guidelines on a number of health issues including:

- zoning
- disease diagnosis
- import risk analysis
- contingency planning
- implementation strategies
- regional capacity building
- pathogens to be considered
- disease surveillance and reporting
- national strategies and policy frameworks, and
- health certification and quarantine measures

Lessons learned from the disastrous viral epizootics experienced in shrimp aquaculture indicate that countries should be more cautious in the international movement of aquatic animals. This is directly applicable to the increasing trade in live groupers. The technical guidelines will assist in making realistic assessment of risks associated with the movement of live grouper. They will guide governments in making careful decisions that will allow movement of live grouper in a responsible and safe way, which does not interfere unreasonably with international trade.

Update on Regional Research Programme on Grouper Viruses

During the last several years, there has been a growing concern over the increasing number of diseases and other health problems of marine finfish (including groupers) experienced by countries in the region. A number of regional workshops recognized the need to give more attention to grouper health management in order to sustain the development of grouper aquaculture:

- Regional Workshop on Sustainable Aquaculture of Grouper and Coral Reef Fishes December 1996, Sabah
- FAO-NACA-OIE, Development of Technical Guidelines on Quarantine, Health Certification and Information Systems for the Responsible Movement of Live Aquatic Animals under the FAO-NACA TCP/RAS/6714. February 1999, Bangkok
- FAO-NACA-DFID-GOB Asia Regional Scoping Workshop on Primary Aquatic Animal Health Care in Rural, Small-Scale Aquaculture Development. September 1999, Dhaka.

The scientific presentations during the recently concluded 4th Symposium on Diseases in Asian Aquaculture (November 1999, Philippines) reflected the scarcity of information and research on grouper health. This lack of information makes it difficult to conduct risk assessments for the responsible movement of live groupers and justifies the need for more concerted efforts to address such concerns.

In view of the above, the Fisheries Working Group (FWG) of the Asia Pacific Economic Cooperation (APEC) has approved support for a one-year project. The project would initiate a survey on the impact of grouper viral diseases and involve a workshop that will provide a platform for discussing current knowledge on grouper health and diagnostic techniques for viral diseases. The project will enable development of a regional programme to support identified research needs, particularly on grouper viral transmission, vaccine development and strategies to reduce the risks of introduction and transfer of pathogens that may be associated with the increasing international trade of groupers. The project will also involve review of options for subsequent funding. FWG 02/2000 has the following objectives:

- Update current knowledge on grouper health, particularly viral diseases, their impact, including standard and rapid techniques for viral disease diagnosis
- Develop a regional programme on grouper health that will assist in reducing losses due to grouper diseases, initially by identifying research needs that will address:
    a) Development of suitable cell lines for grouper viral isolation
    b) Development of techniques for grouper viral identification and diagnosis
    c) Development of protocols for grouper viral disease induction and investigation on modes of virus transmission in grouper
    d) Prevention and control of viral diseases (viral nervous necrosis – VNN, and iridovirus infection) of grouper culture at hatchery stage
- Develop strategies to minimize the risks of pathogen transfer through responsible movement of live grouper
- Identify funding mechanisms that will support the implementation of the regional programme on grouper health
- Strengthen the network of aquatic animal health scientists working on grouper and other marine fish diseases in the APEC region

Based on these objectives, three major tasks identified in the Request for Proposal for the implementation of this project are:

- Task 1: Organize a survey on impacts of grouper viral and other health problems
- Task 2: Organize a workshop “Development of a Regional Research Program on Grouper Virus Transmission and Vaccine Development”

- Task 3: Prepare a report containing the proceedings of the workshop, a synthesis of the grouper viral disease impact survey and economy reviews, regional framework on research for grouper viral disease and other health problems, strategies for responsible movement of live groupers, and options for subsequent funding.

The surveys and workshop werecarried out in consultation with the Aquatic Animal Health Research Institute (AAHRI) of the Department of Fisheries of Thailand and the Network of Aquaculture Centres in the Asia-Pacific (NACA). AAHRI is overseeing the implementation of this project, and NACA is cooperating with APEC in the overall coordination of the Asia-Pacific grouper aquaculture programme.

Conclusions

Health management is an important tool for the prevention of disease in aquaculture and supporting the sustainability of aquaculture production.

This review indicated that the number of diseases affecting grouper has increased steadily with expansion and intensification of grouper aquaculture and trade. Some of the diseases, particularly VER or VNN, and some parasites (*N. girellae* and *C. irritans*) have been described in detail. Other viral infections and diseases of undiagnosed status or unknown aetiology have been reported.

Viral diseases appear to be the most significant diseases that can impact grouper aquaculture. Development of early detection methods should receive priority. These methods are important in making decisions for management, intervention or control.

There is information on farm-level health management techniques in Japan, Singapore, Malaysia, and Thailand. This information can be used for grouper aquaculture.

Risks and impact of a disease vary according to prevailing conditions, therefore, the intervention methods for mitigating the problem may be different. An aquatic systems health management approach is recommended. This approach includes taking into consideration the environment, the host and the pathogen, determining options (cull, treat, quarantine, disinfect) that are available for a specific disease situation, conducting a cost-benefit analysis and proceeding with a good health plan.

Chemotherapy is widely used. It includes a range of chemicals and antiseptic, antibiotics, anti-bacterial treatments and other treatments such as freshwater bath treatments. The development of vaccines is underway, particularly in Japan. Efforts should be made to develop alternative methods for controlling grouper diseases.

Apart from the existing knowledge on infectious diseases affecting grouper, there is very little information on the impact of grouper diseases. More information should be gathered because this is important in prioritizing diseases. The APEC funded project on evaluating the impact of grouper diseases and establishing a regional research framework on grouper health is a well-timed initiative. The framework will hopefully provide solutions to important disease problems in grouper aquaculture and contribute to its sustainability.

As the industry is currently dependent on introduced stock, a more cautionary approach regarding the movement of groupers should be a consideration at the national, regional and international level. The expanding trade in live grouper increases the risks of moving pathogens that may come along with the movement of host fish. There are a number of instruments such as codes of practice, agreements, and technical guidelines aimed at addressing important issues concerning trans-boundary transfer of aquatic animal pathogens.

The success of implementing such codes depend on national programmes that complement and support such agreements through policies, legislation and regulations that protect and sustain aquatic animal production. The trans-boundary nature and commonality of grouper diseases, the need to harmonize approaches to disease detection, and the need to make efficient use of limited resources make a strong case for effective cooperation at the regional and international level.

Continuous support to transparent disease reporting and dynamic exchange of information and technologies is recommended. The FAO-NACA TCP/RAS 6714 provides a solid platform for strengthening collaboration within the Asia-Pacific region towards providing solutions to aquatic animal diseases in Asian aquaculture.

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Feed and Feed Management Practices

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Abstract

The presentation discussed feed availability and current feed management practices in the region with an emphasis on the more common grouper species. While it is acknowledged that aquaculture production can be increased through implementation of sustainable on-farm feeding strategies in semi-intensive and intensive culture systems, most grouper culture in the region involves the culture of wild-caught stocks and the use of locally available, rather than optimal feeds. Culture systems are mainly ponds, pens and floating cages. The requirements of intensive fish culture are strict. Particular attention should be paid to the use of dry feeds, optimal formulations, feed quality and handling, early weaning, automatic feeding, farm site studies and minimization of pollution. An example for this is provided in the paper. The culture of grouper, its nutrition and feeding requirements are presently limited by the dependence on wild-caught stocks. Although there are attempts to make the fry available from hatcheries, the supply is still insufficient for a grouper farming industry.

The Availability and Use of Local Ingredients in Fish Feed for Humpback Grouper Grow-out[3]

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Abstract

The use of expensive imported fish feed ingredients has increased the price of fish feed in Indonesia and consequently reduced the profit of fish farmers. The use of local ingredients, which are much cheaper, would enable the fish farmers to improve their profit. A survey was conducted in South Sulawesi to identify areas with local ingredients that can be used in fish feed. An analysis was applied to determine the nutrient composition of each ingredient. A feeding experiment aimed at determining the optimum protein level in feed for humpback grouper grow-out was carried out in net cages. The main source of protein was local fish meal, and the protein levels applied were 30%, 35%, 40%, 45%, 50%, and 55%. The protein content of the animal source such as trash fish, shrimp head, and blood ranged from 50% to 80%, and of plant source such as rice bran, cassava and oil palm waste ranged from 5% to10%. Feeding experiments showed that feed containing 45% protein resulted in better daily growth and feed conversion ratio than other feeds. Broken-line analysis indicated that the optimal protein content for humpback grouper feed is 45.3%.

Introduction

Feed represents 60% to 70% of the cost in fish culture. The main imported ingredient for fish and poultry feed is fish meal. The use of local ingredients is estimated to have potential to reduce the price of feed up to 40%. Local ingredients, which have potential for substituting imported ingredients, include shrimp heads, silkworm, cotton seed, sugarcane waste and abattoire waste. They are available in many areas in Indonesia, but the exact distribution is still unknown. The survey aimed to identify the location of local ingredient producers as well as the volume.

Humpback grouper is one of the most exportable marine fish and, as a result, is suffering intensive fishing. The culture of this species will help reduce fishing pressure and meet consumer demand. Feed containing the optimal protein level is suspected to be one of the key factors influencing the success of serranids culture (including humpback grouper).Local ingredients are expected to match imported ingredients even though, according to Alava and Lim (1983), the quality of protein depends on amino acid composition, essential amino acid and digestability rate. The protein level for grow-out is usually lower than for larval rearing (Lovell 1980, Boonyaratpalin 1991) and it differs among species. Sakaras et al. (1986) reported that feed with 45% protein and 18% fat resulted in the best growth rate of sea bass. Grouper, *Epinephelus salmoides*, required feed with 40% to 50% protein (Chua and Teng 1980), and *E. malabaricus* with 47.8% protein (Chen and Tsai 1993). Ahmad et al. (1992) found that

[3] Funded by GOI-ACIAR Collaboration Project, FIS/1997/73

a combination of 51% fish meal and 18% soybean meal produced a protein level of 50% with 359 Kcal ME/100 g in feed, which was shown to be suitable for greasy grouper (*E. tauvina*) grow-out. The optimal protein level for humpback grouper (*Cromileptes altivelis*) fry is 54% (Giri et al. 1999). This experiment aims to find the optimal protein level in feed for humpback grouper grow-out.

Material and Methods

The Survey

The site selection for local ingredient producers in South Sulawesi was based on the availability and potential for substitution of imported ingredients. The raw materials were observed in abattoir, cold storage, soybean cake producers, CPO producers, cassava mills and fish landing sites. An analysis of each ingredient covered crude protein using micro Kyeldahl, crude fat using sox let, crude fiber and ash using muffle.

Feeding Experiment

To accommodate the treatments and replicates, eighteen floating net cages, 1x1x1.2 m each were used. They were randomly arranged. The levels of protein tested were 30%, 35%, 40%, 45%, 50%, and 55%. The composition of ingredients in each feed mix is presented in Table 1. Based on a proximate analysis, each feed contains protein, which is very close to the tested level (Table 2). The pellets were produced manually using a meat grinder and dried in sunlight.

Table 1. Ingredient composition (%) of experimental diets

Ingredients	Protein level (%)					
	30	35	40	45	50	55
Local fish meal	34.9	46.9	55.9	66.9	76.9	87.9
Soybean meal	18.0	14.0	12.0	10.0	8.0	5.0
Wheat floor	11.0	10.0	9.0	6.0	4.0	2.0
Rice bran	14.0	10.0	8.0	6.0	3.0	0.0
Fish oil	10.0	8.0	6.0	4.0	2.0	1.0
Squid oil	8.0	7.0	5.0	3.0	2.0	0.0
Mineral mix 1)	1.0	1.0	1.0	1.0	1.0	1.0
Vitamine mix 2)	3.0	3.0	3.0	3.0	3.0	3.0
Ascorbic acid	0.1	0.1	0.1	0.1	0.1	0.1
Total	100	100	100	100	100	100

1) Mineral mix contents (g/kg of mix): calcium 32.5%; phosphorus 10%; Fe 6 g; Mn 4 g; iodine 0.075 g; Cu 0.3 g; Zn 3.75 g; vit. B12 0.5 mg; vit. D3 50,000 IU.
2) Vitamin mix contents (g/kg of mix): vit.A 60,000,000 IU; Vit.D3 12,000,000 IU; vit.E 120,000 mg; vit.K3 12,500 mg; vit.B110,000 mg; vit.B225,000 mg; vit.B6 10,000 mg; vit.B12 100 mg; vit.C 150,000 mg; folic acid 5,000 mg; nicotinic acid 60,000 mg; D-pantothenic acid 50,000 mg; Dl-methionine 50,000 mg; biotin 125 mg.

Table 2. The results of proximate analysis of experimental diets for humpback grouper

Nutrient	Protein level (%)					
	30	35	40	45	50	55
Crude protein	31.99	36.62	41.39	46.53	49.51	55.43
Crude lipid	21.60	20.00	16.58	12.28	10.17	6.99
Crude sugar	1.75	1.60	1.71	1.58	1.39	1.35
Crude fibre	2.25	1.80	1.41	1.44	0.87	0.46
Crude ash	12.37	14.61	16.16	18.45	19.46	21.46
Moisture	9.30	9.45	9.20	9.65	12.60	12.87
Calori (k.cal/g)	5.49	5.13	5.03	5.02	5.00	4.87

Fifteen fish per cage (17.34+2.10 g/fish) were fed dry pelleted feed twice a day at 07:00 and 16:00 to satiation. Weighing was carried out every thirty days. The variables observed were daily growth rate, feed conversion ratio, protein efficiency ratio and daily feed consumption.

Water quality was observed every morning at 0600, and in the afternoon at 1600. The parameters observed included dissolved oxygen, salinity and temperature. A YSI DO-meter was used to measure dissolved oxygen and temperature. Salinity was measured using a refractometer.

Results and Discussion

The Survey

The volume, price, and season of the local ingredients available in South Sulawesi are presented in Table 3. Figure 1 shows locations of the producers of each local ingredient. The volume of trash fish in Luwu Regency is 9,691 mt/year, and the price in season (Rp 1.500/kg) did not vary much from the off season price (Rp 2.000/kg). Luwu Regency is the main trash fish producer, followed by Takalar, Barru, and Selayar Regencies.

Makassar is the main producer of blood meal. The abattoir produced more than 38,000 mt followed by Tana Toraja, Bulukumba and Bone Regencies. Makassar is also one of the main producers of shrimp-head and palm-oil waste (41,354 mt) after Luwu (125,000 mt) and Mamuju (100,000 mt). Palm oil waste is a good source of plant fat.

Rice bran is found all over South Sulawesi, but the main producers are Luwu, Bone, Wajo, and Sidrap. High quality rice bran is a good source of plant protein, fat and fibre. Cassava cake, a source of carbohydrate, is produced mainly in Gowa and Enrekang regencies.

Based on the availabilityt, Luwu Regency is a potential producer of local ingredients for fish and poultry feed. Unfortunately, Luwu Regency is the farthest Regency from the provincial capital city, Makassar.

The Feeding Experiments

Within sixty days, the weight of fish increased by 73.9% to124%. The weight gain increased and reached a turning point at a protein level of 45% (Table 4). In fact, the feed with 45% protein resulted in the best daily growth rate and feed conversion ratio.

The protein efficiency ratio was not different among fish fed diets with 30%, 35%, 40%, and 45% protein. The level of protein higher than 45% significantly decreased the protein efficiency ratio. The feed conversion ratio was not significantly different among the feeds except diets with 30% protein. The daily growth rates of the fish fed diets with 30% and 55% protein were not significantly different but they were significantly lower than the daily growth rates of the fish fed other diets.

Based on the broken-line analysis of daily growth rate data, the protein requirement for maximum growth of humpback grouper weighing 25 to 40 g/fish is 45.23%. Giri et al. (1999) reported that protein requirement for grouper is relatively high, about 47.8% to 60%, compared to the protein requirement for yellow tail (*Seriola quinqueradiata*) which is about 43,1% (Ruchimat et al. 1997). One of the factors affecting protein requirement is the raw material (Chen and Tsai 1993, Giri et al.1999).

Table 3. The main areas of local ingredients that can be used in fish feed

Regency	Trash fish			Blood meal	Mysid	Shrimp head meal	Rice bran	Cassava cake	Palm oil cake
	Anchovy	Sardine	Ponyfish						
Luwu	5,795.4	2,513.4	1,382.4	3,353	-	-	59,538	-	125,000
Wajo	204.3	308.9	533.1	1,615	46.2	-	42,882	-	-
Bone	920.1	936.8	503.1	4,373	-	36.8	57,682	-	-
Sinjai	238.3	1,661.5	45.7	3,374	4.9	-	8,606	-	-
Bulukumba	226.5	1,585.9	690.7	4,454	-	-	16,683	-	-
Selayar	1,025.9	913.3	440.9	711	57.5	-	470	-	-
Bantaeng	70.7	694.3	39.6	1,694	1.0	-	8,033	-	-
Jeneponto	549.7	1,796.6	463.1	1,404	2.4	-	6,269	-	-
Takalar	339.0	2,632.5	1,759.0	957	-	-	11,675	-	-
Gowa	-	-	-	3,591	-	-	22,177	228,000	-
Makassar	490.2	2,143.4	412.1	38,098	-	2,025.8	1,530	-	41,354
Maros	1,126.1	780.7	51.9	2,078	-	-	19,178	-	-
Pangkep	-	1,672.9	236.8	3,227	57.1	-	11,380	-	-
Barru	1,479.3	1,651.4	18.5	1,881	-	-	8,506	-	-
Pare-pare	411.6	336.6	-	2,252	-	-	124	-	-
Pinrang	758.6	1,821.7	488.9	2,796	-	-	29,825	-	-
Polmas	942.8	810.2	532.6	1,728	23.9	-	28,329	-	-
Majene	28.3	77.0	2.7	511	-	-	1,751	-	-
Mamuju	299.4	343.7	33.9	365	-	-	15,098	-	100,000
Sidrap	-	-	-	3,541	-	-	36,400	-	-
Soppeng	-	-	-	2,404	-	-	15,998	-	-
Enrekang	-	-	-	2,008	-	-	5,235	7,488	-
Tanatoraja	-	-	-	7,774	-	-	13,993	-	-
Annual tonnage	14,906.2	22,680.8	7,635.0	94,189	193.0	2,062.6	421,361	235,488	291,354
Dry product (+)	5,058.2	6,902.0	2,021.8	-	19.3	928	-	117,744	116,541
Price (Rp/kg)	1,500-2,000	1,500-2,000	1,500-2,000	-	5,000-7,500	50 (wet) 2,500 (dry)	250-700	100	250
Competition with human/industry	+++	+++	+++	-	+++	+	++	++	++
Seasonality	Dark moon Agt.-Nop	Dark moon Agt.-Nop	Dark moon Agt.-Nop	All year around	July-Sept.	All year around from cold storage	All year around	All year around	All year around
Gear	*Rambo* floating lift net	*Rambo* floating lift net	*Rambo* floating lift net	-	*Sudu* scop net	-	-	-	-

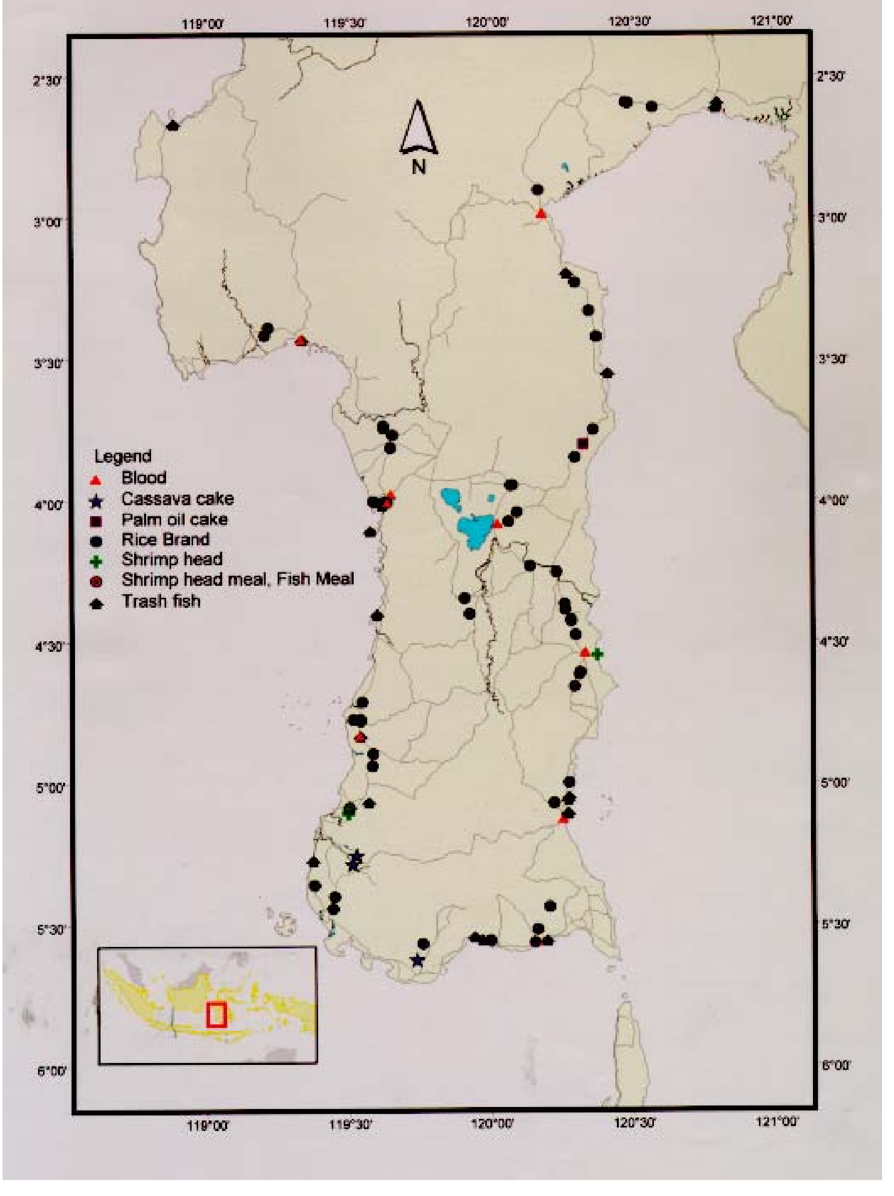

Figure 1. Distribution of local feed ingredients in South Sulawesi

Table 4. Performance of humpback grouper at different levels of dietary protein

Variables	Protein level (%)					
	30	35	40	45	50	55
Initial weight (g/ind.)	14.2	15.8	16.9	17.5	19.3	20.2
Final weight (g/ind.)	24.8	32.5	35.4	39.3	39.8	40.6
Weight gain (%)	73.9	105.7	109.5	124.0	106.2	101.0
Survival rate (%)	97.8^{a}	95.6^{a}	97.8^{a}	95.6^{a}	95.6^{a}	100.0^{a}
Daily growth rate (%/d)	0.92^{a}	1.21^{ab}	1.23^{ab}	1.35^{b}	1.22^{ab}	1.16^{a}
Food conversion ratio	2.37^{a}	1.87^{b}	1.69^{b}	1.53^{b}	1.63^{b}	1.73^{b}
Daily food consumption (% bw/d)	2.14^{a}	2.10^{a}	1.97^{a}	1.91^{a}	1.85^{a}	1.91^{a}
Protein efficiency ratio	1.32^{a}	1.46^{b}	1.42^{b}	1.40^{b}	1.24^{a}	1.04^{c}

A changing pattern of the protein efficiency ratio is reported for carp (Ogino and Saito 1970, Jauncey 1982), tilapia (Mazid et al.1979), snakehead (Wee and Tacon 1982) and malabar grouper (Chen and Tsai 1993). The pattern is similar to the pattern in this experiment. Generally, an increase of the protein level in feed is always followed by a decrease in the protein efficiency ratio.

The water quality variables (Table 5) were not distinctively different among treatments. The dissolved oxygen was in the optimal range, 2.7 to 7.3 mg/l, for fish growth, as were salinity and water temperature.

Table5. Water quality variables measured during the experiment

Treatments	Time	Temperature (^OC)	Dissolved oxygen (ppm)	Salinity (ppt)
30	06.00	21.7 - 29.8 (26.5 ± 2.16)	3.1 - 7.2 (4.6 ± 0.9)	30-34 (32.6±1.42)
	16.00	22.8 - 31.7 (27.5 ± 2.3)	3.8 - 7.3 (5.8 ± 1.0)	30-34 (32.6 ± 1.40)
35	06.00	22.7 - 29.8 (26.6 ± 2.0)	3.2 - 6.9 (4.7 ± 0.8)	30-34 (32.6±1.42)
	16.00	23.4 - 31.1 (27.6 ± 2.1	3.8 - 7.3 (5.7 ± 1.0)	30-34 (32.6 ± 1.40)
40	06.00	22.6 - 29.8 (26.6 ± 2.1	3.1 - 7.3 (4.7 ± 0.9)	30-34 (32.6±1.42)
	16.00	23.2 - 31.2 (27.6 ± 2.1)	3.8 - 7.1 (5.7 ± 1.3)	30-34 (32.6 ± 1.40)
45	06.00	21.5 - 29.8 (26.6 ± 2.2	2.7 - 7.1 (4.6 ± 0.8)	30-34 (32.6±1.42)
	16.00	23.0 - 31.2 (27.6 ± 2.1)	3.8 - 7.1 (5.7 ± 1.0)	30-34 (32.6 ± 1.40)
50	06.00	21.6 - 29.8 (26.5 ± 2.2)	3.2 - 7.1 (4.6 ± 0.8)	30-34 (32.6±1.42)
	16.00	23.2 - 31.1 (27.6 ± 2.1)	3.8 - 7.1 (5.7 ± 1.0)	30-34 (32.6 ± 1.40)
55	06.00	22.3 - 29.8 (26.6 ± 2.1)	3.0 - 7.4 (4.7 ± 0.9)	30-34 (32.6±1.42)
	16.00	23.0 - 31.2 (27.6 ± 2.2)	3.8 - 6.9 (5.7 ± 1.0)	30-34 (32.6 ± 1.40)

Except for dissolved oxygen, other water quality variables did not fluctuate significantly. The concentration of dissolved oxygen in the afternoon (5.7 to 5.8 mg/L) was not much different from that in the morning (4.6 to 4.7 mg/L), indicating oligotrophic waters. The effects of wild organisms on the results of this experiment could be neglected.

In mesotrophic waters, wild species of fish and other organisms are usually more abundant than in oligotrophic waters. Fish raised in mesotrophic waters grow faster than those cultured in oligotrophic waters. There is a possibility that if the experiment were conducted in mesotrophic waters, the fish would grow faster and demonstrate better feed conversion and protein efficiency ratios.

Conclusion

Local ingredients, which could be used as substitutes for imported ingredients in grouper feed, are available all year around in large quantities from South Sulawesi. A feed mix with 45% protein containing local fish meal, rice bran and soybean meal supported the maximum growth of humpback grouper.

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Environmental Management of Mariculture: The Effect of Feed Types on Feed Waste

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Abstract

This paper provides the results and discussion of feed waste experiments conducted in floating cages in Hong Kong. Comparisons of feed waste generated from moist pellet and trash fish are provided. Information on solid wastes generated from mariculture activities in Hong Kong is also given. Nitrogen loss and nitrogen retention of areolate grouper grown on different diets are illustrated in the form of diagrams.

Mariculture: Environmental Considerations

Adverse environmental impacts of aquaculture have become a major concern in many countries (Rosenthal, 1994, Wu, 1995). It has been estimated that some 75% to 85% of C, 40% to 80% of N and 65% to 73% of P input into a marine fish culture system will be lost into the environment, contributing to water and sediment pollution (Bradbury and Gowen 1987; Ackefors and Enell 1994; Talbot and Hole 1994; Wu 1995). Feed wastage, excreted N (and hence carbon and nutrient input) can be significantly reduced when trash fish are replaced by pellet feed (Ove Arup 1989; Hansen et al. 1990; Wu et al. 1994; Wu 1995). Consequently, the use of trash fish as fish feed is being regulated in some countries. In Denmark, for example, the use of trash fish was banned, and fish farms had to switch to the use of formulated feeds (Gordard 1996).

Compared to pellet feed, the use of trash fish leads to a much higher feed waste (Ove Arup 1989; Hansen et al. 1990). The particle size of feed waste generated from trash fish is much smaller, leading to a wider dispersion and greater impact upon a larger area (Wu et al. 1994). Apart from settled wasted feed, suspended solid waste and dissolved waste were also higher. This is because the leaching rate of trash fish is significantly higher than that of semi-moist feed which contains suspended solids: two to four times higher; total organic matter: two to six times higher; total nitrogen: four to ten times higher; inorganic phosphate: five times higher) (Ove Arup 1989; Hansen et al. 1990).

Nitrogen excretion of culture fish fed with trash fish is also much higher than excretion of those fed with pellet feed because of the poor FCR of a trash fish diet (Leung et al. 1996). Excessive nitrogen is excreted by fish and contributes to nitrogen of eutrophic waters. Poor feed quality also increases waste output (Ackefors and Enell 1994; Cho et al. 1994; Nijhof 1994; Talbot and Hole 1994). Since it is not practical to control effluents in open water cage culture, improving and regulating feed quality may be one measure to reduce waste generated by the aquaculture industry. In Denmark, for example, maximum FCR, protein, phosphate and the minimum of gross energy and digestible energy are being regulated (Table 1). Feeding fish with highly digestible components with a balanced energy level (high-nutrient-dense diets) reduces waste and pollution loadings (Cho et al. 1994). Obviously, such manipulation is only possible when pellet feed is used instead of trash fish.

In Hong Kong, where trash fish are used as feed, marine fish culture activities are responsible for 3% of total biological oxygen demand (BOD), 3% of total nitrogen loading and 20% of total solid loading of total domestic and industrial sewage discharges into the coastal waters. Sixty-five percent of these pollution loadings were derived from feed wastage alone (Ove Arup 1989). Feed waste is the single most important pollution source in aquaculture. This study compared feed waste resulting from the use of trash fish and a formulated diet for grouper in an open cage culture environment in order to estimate the reduction in pollution load by using pellet feed.

Table 1. Danish regulations for aquafeeds (from New, 1995)

	Before 1/1/90	1990-1991	After 1/1/92
Maximum FCR	1.2	1.1	1.0
Minimum GE (MJ/kg)	23.4	23.9	25.1
Minimum DE (%)	70.0	74.0	78.0
Maximum Nitrogen	9.0	9.0	8.0
Maximum Protein (% as fed)	50.6	50.6	45.0
Maximum Phosphorous (% digestible matter)	1.1	1.1	1.0
Maximum Phosphorous (% as fed)	1.0	1.0	0.9
Maximum Dust (%)	1.0	1.0	1.0

FCR=feed conversion ratio; GE=gross energy; DE=digestible energy

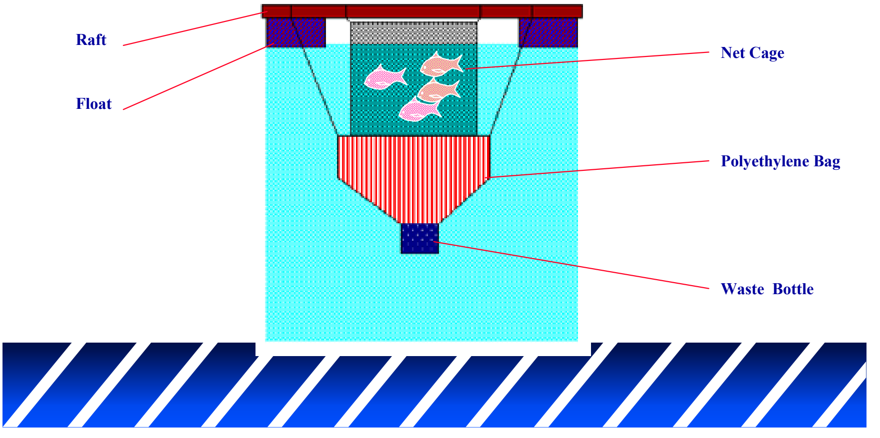
Materials and Methods: Feed Waste Experiment

Field experiments were conducted in Kat O Fisheries Research Station, Hong Kong using twelve net cages (LxWxD =1.5x1.5x1.5 m). Each cage was stocked with 122 to 141 adult areolate groupers (wet weight: 94g to 124g per individual). There is no established method to estimate the feed waste in open water cages. In this study, a suspended waste pen (Plate 1) was used to collect the wasted feed. Wasted feed was collected in the collecting bottle at the conical tip of the pen. The four sides of the cage were left open to allow water movement between the inside and outside of the cage to minimize stress to the fish.

Four feed collecting devices were set up. Experimental fish in the cage were starved for twenty-four hours prior to the experiment. The fish were allowed to acclimate for one hour after the installation of the units. At the beginning of the experiment, fish were fed with P50L20 by hand to satiation. The amount of feed applied to each cage was recorded. During feeding, underwater observation was made by SCUBA divers using underwater videography and photography. The purpose of underwater observation was to monitor and ensure that the traps would efficiently collect unconsumed feed. After feeding, waste feed was allowed to settle for one hour. The waste feed was then collected by SCUBA divers and dried at 85^{o}C to determine the dry weight. Four cages without traps were set up as controls. The purpose of the control was to observe whether the installation of waste traps would cause any stress and affect the normal feeding of the fish. Feed waste was expressed as a percent of dried, unconsumed feed. The feed waste of fish fed with trash fish and moist pellet feed were determined.

Plate 1

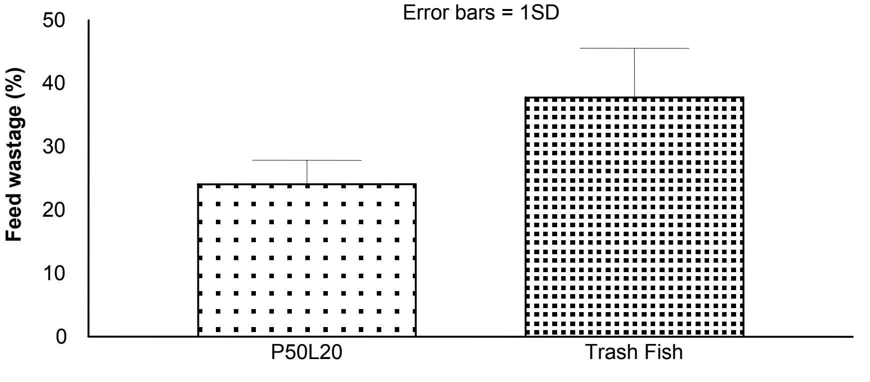
Suspended Waste Pen



Results

The amount of feed waste from pellet feed was (±SD) 24.1±3.8%, which was significantly lower ($p<0.05$) than that of trash fish (37.8±7.8%) (Fig.1). Underwater observations indicated that more fine particles were generated around the cage when trash fish was used.

Figure 1 **Feed waste of moist pellet and trash fish**



Discussion: Environmental Considerations

The present experiment clearly demonstrated that feed waste was significantly reduced when trash fish was replaced by pellet feed. In 1989, the solid waste generated from the local mariculture industry in Hong Kong was 20,760 mt (Table 2), 65% of which (13,500 mt) was from uneaten feed. Based on experimental data obtained in the present study, solid wastes could be reduced by 5,433 mt (40%) if pellet feed was used instead of trash fish. The sinking rate of the pellet feed used in this study was 0.037 to 0.083 m s^{-1}, which was relatively high compared with trash fish (0.014 to 0.027 m s^{-1}). Since areolate grouper is a mid-water feeder, feed waste may be further reduced if the residence time of the feed in the water column can be increased. If the sinking rate of pellet feed is reduced (by employing extrusion technology), then feed waste could be further reduced, which would increase the feeding efficiency and reduce pollution loads.

Table 2. Solid wastes generated by mariculture in Hong Kong (in mt yr^1)

	Trash Fish	Pellet feed
Uneaten feed	13,500	*8,067
Dead fish	720	720
Fish faeces	926	926
Fouling organisms	5,300	5,300
Human waste	65	65
Dog faeces	195	195
Total	20,706	15,273
	Ove Arup, 1989	*from the present study

Foy and Rosell (1991) proposed that nitrogen loss in a fish farm depended on the feed conversion ratio of the feed and the nitrogen content of the fish, which can be described by the following model:

N loss = (FCR x N content of the feed)- N content of fish produced

Since feed wastage was not included in the FCR in our experiment, the model can be modified as:

N loss = (FCR x N content of the feed)- N content of fish produced + N content of wasted feed

In addition, the percentage nitrogen retained in a fish body may be calculated by the following equation:

% N retained = (N content of fish produced) / (FCR x N content of the feed + N content of wasted feed)

N loadings resulting from the use of trash fish and the various experimental diets were compared using the above models (Figure 2). N loading resulting from the use of trash fish was 17 times higher than that resulting from the use of moist pellets with 20% lipid and 50% protein. Surprisingly, only 8.1% of the nitrogen was retained in the fish body when trash fish was fed to areolate grouper, while 62% of the N was retained when moist pellet with 50% protein and 20% diet was used as feed (Fig. 3).

Figure 2. Nitrogen loss of areolate grouper when fed with different diets

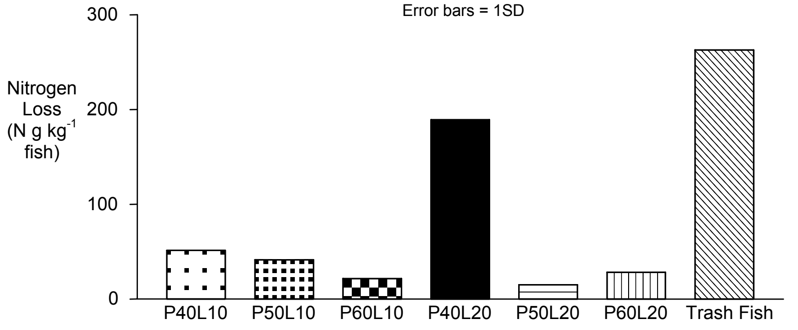
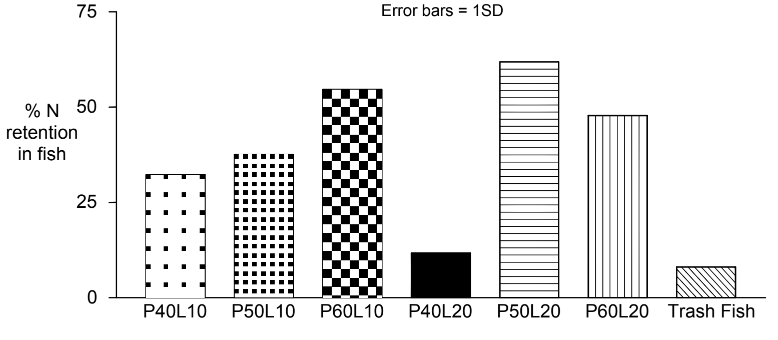


Figure 3. Nitrogen retention of areolate grouper when fed with different diets



Legends

P40L10 Moist Pellet With	40%	protein	10%	lipid
P50L10	50%		10%	
P60L10	60%		10%	
P40L20	40%		20%	
P50L20	50%		20%	
P60L20	60%		20%	

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Grouper Aquaculture in Myanmar

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Abstract

This presentation provides background information on the fisheries and aquaculture development in Myanmar. The grouper aquaculture status in Mynamar is also being described. Commercially important grouper species for mariculture were identified, and some of the grouper species that are common in Myanmar waters are provided. The basic culture techniques for grouper nursery and grow-out adopted are briefly introduced. Future research and development requirements for grouper aquaculture in Myanmar are also identified.

Introduction

The fisheries of Myanmar are of paramount importance as a source of animal protein. They provide income through employment and generate foreign currency. Myanmar is one of the few countries in the Asian region endowed with rich fish resources both inland and marine that are not yet fully used. Several resource surveys indicate a potential yield of marine fishery resources to be approximately 1.05 million mt and that approximately 60% to 70% of MSY has been harvested in the present year. This indicates a possible under-use of the marine living resources of Myanmar.

The Union of Myanmar has a total coastline of 2,832 km. It can be divided into three coastal regions: the Rakhine Coastal Region (from the mouth of the Naaf River to Mawtin Point, about 740 km in length), the Ayeyarwady Delta and the Gulf of Mottama (Martaban) Coastal Region (from the Mawtin Point to the Gulf of Mottama, about 460 km in length) and the Tanintharyi Coastal Region (from the Gulf of Mottama to the mouth of the Pakchan River, about 1,200 km in length) in the Bay of Bengal and in the Andaman Sea. The population growth rate during 1988 to 1998 was 20.8%, while fish production during this period was 2,235.8%. The consumption of fish per capita has varied from 17.5 kg to 18 kg during the last decade.

Fisheries Development Objectives

The national objectives for the fishing industry are to effectively contribute to the national economy and the socioeconomic conditions of the people. Myanmar fisheries development has been concentrated on short, medium and yearly plans.

The aims and objectives of the fisheries sector are:

- To increase year-round production
- To produce quality seeds and strains
- To conserve freshwater and marine fisheries resources
- To expand production of freshwater fish for domestic use

- To upgrade the socio-economic status of fisheries communities
- To promote mariculture in order to increase foreign currency earnings
- To earn more foreign currency and promote investment in fisheries sectors, and
- To increase fish production for domestic consumption and export the surplus

History and Present Status

Aquaculture has a long tradition in Southeast Asia. Ponds and lakes have been used for fish farming for centuries. Aquaculture comprises a variety of activities from intensive pond or raceway culture to stocking in natural waters and relatively minor manipulations of wild stocks. In spite of differences in aquacultural activities, aquaculturists face similar problems and require similar scientific and technical information. They need information on selection of species to culture, the best type of feed, disease control, construction of ponds, and maintenance of adequate physical and chemical conditions of water.

Aquaculture in Myanmar is limited to freshwater finfish, crustaceans and one marine species. A brief review of available literature indicates a wide array of species for culture, including finfish, crustacean, mollusks, and even reptiles. Informal interviews with individual producers in the various sectors of the aquaculture industry indicate that there is a need to establish a basis for assessment of aquaculture potential.

Extensive fish farming has been practiced in Myanmar, particularly in Rakhine State, adjacent to Bangladesh. While the shrimp aquaculture industry has been developing rapidly in recent years in the ASEAN countries, Myanmar is embarking on modernizing its industry. There are currently about 30,000 acres (12,000 hectares) of traditional fish farms in operation, which are mainly located in Rakhine State bordering Bangladesh. Because of the traditional method (trap and hold), the yield from those ponds is very low at 100 kg/ha/yr.

In 1991-1992 fish and prawn culture pond area was 17,215.8 hectares. It increased to 47,475 hectares in 1998-1999 (including 25,346 hectares of prawn and shrimp culture pond area and 22,229 hectares for fish culture pond area).

In 1981-1982, fish and prawn production from aquaculture fisheries was 2,941.17 mt; it increased to 85,017.97 mt in 1998-1999.

In 1988-1989, the total exportable fisheries products were 5,431.60 mt valued at US$ 10.20 million. In 1998-1999, exported fisheries products were 126,873.73 mt and valued at US$ 201.32 million. Myanmar fisheries product are exported to forty-two countries, including European Union (EU) countries.

EU countries offer higher prices than Asian countries for Myanmar fishery products. To control food safety, the Quality Control Unit of the Department of Fisheries has introduced the HACCP (Hazard Analysis Control Critical Point) system for processing plants and inspection systems according to importing countries.

There are eighty processing plants in Yangon and Coastal Regions. Shrimp and prawn are processed mainly in 2 kg and 1.8 kg blocks and are exported to Japan, UK, USA, Singapore, Hong Kong and Belgium. Some of the factory products in frozen, whole, gutted or filleted form are exported to Saudi Arabia, Australia, Hong Kong, Singapore, China and Malaysia.

Grouper Culture

Groupers, *Epinephelus* sp., popularly known as "Kyauk Nga" or "Nga Tauk Tu" in Myanmar dialects, are important marine fishes belonging to the Family Serranidae.

The demand for grouper in the international market (particularly in Japan, Singapore and Hong Kong) is growing fast. Export price is expected to increase in the near future. Live market size groupers have strong export potential and grouper farming could become a source of hard currency for the country. Grouper farming likewise could offer an alternative to shrimp farming, an industry presently beset by diseases and environmental problems.

The development of grouper culture is one of the most important targets of aquaculture on the tropical coast. This fish is easy to culture, it grows fast, it has white and tender meat and is considered a suitable choice for commercial scale culture. This fish is favoured in Singapore, Malaysia, Chinese Taipei and Thailand and Hong Kong. The market price of grouper is higher than that of seabass. A live fish (1 kg) is priced at US$ 6.5. Grouper culture can generate a high income and provide farmers with good profit. It can be extended to industrial scale.

Groupers are cultured in Myanmar using fry and juveniles caught from the wild. Fish farmers grow them in net cages and ponds. Presently, the floating net cage culture of groupers is conducted in the coastal areas at the southern and western part of Myanmar (Myeik Archipelago and Gwa township). Most of grouper seeds for culturing are obtained from the wild.

Commercially Important Grouper Species for Mariculture

There are around twenty species of groupers in Myanmar waters, but so far only four species are cultured commercially. They are:

- *Epinephelus coioides*
  Orange spotted grouper (Myanmar name Goung Lone)
- *Epinephelus malabaricus*
  Black spotted grouper (Myanmar name Goung Lone Anet Pyauk)
- *Epinephelus bleekeri*
  Duskytail grouper (Myanmar name Bather Pyauk)
- *Epinephelus tauvina*
  Greasy grouper (Myanmar name Goung Lone)

Collected Grouper Species from Mvanmar Waters

Epinephelus merra	*Cephalopholis boenak*
Epinephelus coioides	*Epinephelus undulosus*
Epinephelus tauvina	*Epinephelus maculatus*
Cromileptes altivelis	*Plectropomus areolatus*
Cephalopholis argus	*Epinephelus labriformis*
Epinephelus bleekeri	*Epinephelus sexfasciatus*
Epinephelus fasciatus	*Plectropomus maculatus*
Epinephelus analogus	*Epinephelus malabaricus*
Epinephelus megachir	*Epinephelus fuscoguttatus*
Epinephelus areolatus	*Anvperodon leucogrammicus*

Source of Fry and Fingerlings

At present, the grouper fry for commercial cage and pond production are still from the wild. Grouper fry are collected using various devices including rock mounds, brush piles, brush lures, and fish traps.

Site Selection For Cage Culture

The criteria for selecting a suitable site are:

- *Salinity range: 20% to 32%*
  This salinity range is available all year in Than Dwe township and Gwa township (in Rakhine coastal areas) and Maw Tone Gyi, Kyun Su township (in Tanintharyi coastal areas).
- *Water depth: over two meters at low tide*
  This is due to the unusual size of the culture cage, which is 5 x 5 x 2 meters. In Maw Tone Gyi grouper Culture station, they are using floating net cages 10’ x 10’ x 10’ each and the water depth is about thirty to forty feet.
- *Current and waves: protected from strong winds, waves and currents*
  Ideal areas are protected bays, sheltered coves, and similar protected waters. Grouper culture station in Than Dwe township is situated in Andrew Bay or Mayo Bay and the station in Gwa township is situated in Amaw or Tin Taw sheltered coves, which are protected form strong winds, waves and currents.
- *Water quality: free from domestic, industrial and agriculture pollution*
  Grouper culture stations in Myanmar are relatively free from water pollution.
- *Water circulation*
  All grouper culture stations in the country have water circulation sufficient to maintain water quality and prevent waste materials from accumulating under the net cage.

Culture Technique

Grouper culture in the country is by floating net cage. The net cages are hung on GI pipe, wooden or bamboo frames. These cages are kept afloat by Styrofoam drums, plastic carboys or bamboo. The cage dimensions are 15 x 15 x 15 feet in Gwa grouper culture station, 15 x 15 x 10 feet in Tan Dwe grouper culture station and 10 x 10 x 10 meters in Myeik Station. There are thirty-six cages in Gwa, sixteen cages in Tan Dwe and about three hundred cages in Myeik**.** The cages are stabilized with concrete weights at each corner.

Nursery

Grouper fry are collected from the wild for culture in net cages. Grouper fry are from 7 cm to 17.5 cm long; they are usually collected by fish traps set in coastal waters near mangrove areas. The price of a grouper fry is 100 to 130 kyats. Fry are collected all year but the supply is most abundant from March to July. The stocking density in the nursery is 250 per cubic meter. In Myeik, fry are collected by handlines or poles and lines.

Grow - out

Groupers are reared in cages for nine to ten months to a market size of 250 grams. The live fish are mostly exported by sea to China, Hong Kong, China and Chinese Taipei. Other grouper exports are frozen groupers and fillet. The present export price of grouper more than 335 grams in weight is US$ 6,500 per mt (US$ 15,000 per mt for a table size grouper in restaurants). The export volume of live groupers was US$ 143,659 in 1997, US$ 239,142 in 1998, and US$ l40,433 in 1999 (Production of Pyi Phyo Htun Co. Ltd.).

Trash fish is the main feed for grouper culture in Myanmar. Feeding is done once a day in the morning. Since trash fish is insufficient and expensive, feeding is done only twenty days in one month. The fish are fed slowly and feeding is stopped when the fish no longer come up to the surface.

The cages are checked once or twice a month to ensure they are not damaged. Nets are cleaned or changed every month. Net changes allow the culturist to check the number of fish and their health condition.

Diseases and Prevention

Among mariculture types or sea farming systems, the grouper culture is capital intensive. Disease may cause significant losses. Numerous diseases of grouper have been reported in neighboring countries. The causative agents of these diseases are parasitic organisms, bacteria, viruses, malnutrition, and environmental stress.

At present, there are no significant mortalities because of diseases. A high quality feed, appropriate stocking density and suitable water quality at the culture site are preventive measures in Myanmar.

Other Marine and Brackish Water Aquaculture

Aspects of experimental culture of seabass (*Lates calcarifer*), mullet *(Mugil* sp.), and milk fish *(Chanos chanos*) have been studied by the Marine Biology Department and Department of Fisheries for the last twenty years. Due to the lack of technology and hatcheries, finfish aquaculture is still not well developed.

Seabass (Lates calcarifer)

Sea bass farming is introduced in some of the Ayeyarwady Delta areas. In collaboration with the FAO, the Myanmar Forestry Department has implemented "The Environmentally Sustainable Food Security and Micro-Income Opportunities in the Ayeyarwady (Mangrove) Delta Project (MYA/96/008)" in Delta areas.

Seabass fingerlings can be caught from August through October throughout the project areas. They are about 10 cm in length, ideal for stocking in pens, cages and grow-out ponds. Fingerling survival is high, and predators are less of a problem with a top carnivore like seabass. Small seabass are sold in fish markets, but the price is very low. A fingerling purchased for 18 kyats to 20 kyats can be reared to an 800 gram fish with a farm gate value of 200 kyats.

Mud crab (Scylla serrata)

Mud crab (*Scylla serrata*) culture in mangroves or tidal flats has been practiced mainly in the Ayeyarwady Delta areas. It is ecologically friendly because it does not destroy mangrove and uses locally available low cost materials. Most farming is practiced in ponds (fattening crab can be raised in ponds), bamboo enclosures and cages located in river and canal systems. Culture densities for ponds and cages are two to four juveniles per m^2 (weighting 25 to 40 gram/piece) and 10 to 25 kg per m^2 respectively. Chopped trash fish, *Ascetes* and agricultural by-products are used for feeding crab.

After six to seven months, marketable crab (200 - 250 g/piece) is harvested by handpicking during low tide. With a survival rate of 40% to 60%, the yield could be 275 to 600 kg/ha/crop. Mud crab can also raised with shrimp. It is possible that mud crab may help mitigate water pollution in shrimp ponds.

Trade in mud crab (*Scylla serrata*) is thriving in the delta region. A large part of the production is for export to Singapore and China. Smaller crabs are marketed in China. Since crabs must arrive live at their final destination, the trading network from the delta region to Yangon Airport for export is well organized.

Seaweeds

If they are properly used, seaweeds can be a dependable natural resource for Myanmar. No detailed or systematic estimates on harvestable quantities from natural beds of seaweeds have been made in Myanmar's coastal areas. Ecological studies on intertidal and subtidal algae are needed. Based on a combination of data from transects including quadrates and numerous visual observations, the following constitutes the economic potential of seaweed genera of Myanmar.

- Chlorophyta (green algae)

  Ulva, Enteromorpha, Monochrome, Caulerpa and *Codium*

- Phaeophyta (Brown Seaweed)

  Padina, Dictyota, *Spathoglossum Chnoospora, Rosenvingea*, *Hormophysa Turbinaria,* and *Sargassum*

- Rhodoyhyta (Red Seaweed)

  Porphyra, Gelidiella, *Halymenia*, *Sosieria*, *Catenella*, *Hypnea*, *Gracilaria, Laurencia* and *Acanthophora*

Among these genera, *Sargassumn* and *Hypnea* are more abundant than other seaweeds. Estimated potential is 2,500 mt dry weight for the former and 1,500 mt in dry weight for the latter. So far, there are no mariculture industries for seaweed in Myanmar.

Marine Shrimp Culture

Background

In Myanmar, marine shrimp farming has been practiced for the last twenty-five years. Wild shrimp fry are trapped in the salt beds and paddy fields around estuarine areas during tidal water exchange, or are intentionally gathered from the wild and stocked directly in ponds. Production depends on the seasonal abundance of wild fry, which fluctuates widely from year to year.

In 1997**,** Myanmar successfully spawned and partially reared larvae of giant tiger prawn (*Penaeus monodon*). The Department of Fisheries encouraged additional seedstock from hatcheries to supply traditional ponds**.** Supplemental feed was given in this semi-intensive shrimp farming system

Actual and Potential Shrimp Production

In Myanmar**,** the giant tiger shrimp *(Penaeus monodon)* is the only mariculture species because of its rapid growth and high export value. The culture techniques in the country are extensive (traditional) and semi-intensive. In 1997**,** there were about 30,000 acres (12,000 hectares) of traditional shrimp farms in operation, mainly located in Rakhine State bordering with Bangladesh. The yield from the ponds is very low.

Current Technology

Almost all farms use extensive technology. There are 65,967.13 acres of marine shrimp ponds, including 65,787.66 acres (99.7%) of traditional or extensive ponds and 179.47 acres (0.3%) of semi-intensive ponds.

Ponds that use extensive technology are very large, usually exceeding fifty ha. The productivity of extensive culture is extremely low at 80 kg per hectare. Shrimp fry are carried to the enclosed area by the tide and trapped during the growing season. Stocking density is unknown.

Semi-intensive farms use standard technology transferred from Indonesia. Hatchery fry are stocked at different rates (depending on availability). Stocking rates as high as 375,000 per hectare can be used. Productivity is high (2,500 kg per hectare).

Hatchery Technology

Seed production techniques for *Penaeus monodon* were developed in recent years in Myanmar. Biologists from several countries (especially Asian countries) were trained in these techniques. There are two types of hatchery techniques: the big-tank and small-tank hatchery (backyard hatchery).

At present, there are only seven shrimp and prawn hatcheries in the country. In order to increase production of the marine shrimp fry, three new backyard hatcheries are under construction. A new, large hatchery is also being constructed in Sittwe, Rakhine State, with the aid of the Thai government.

In 1998-1999, total seed production of marine shrimp from all hatcheries was 29.142 million.

Future Research and Development Requirements

One of the major constraints to aquaculture development has been the inadequate supply of seed for culture purpose. This is especially true in the case of marine finfish culture. It is likely that the successful development of hatchery technology, together with improvement and development of appropriate culture systems will lead to diversification and accelerate the pace of aquaculture development in Myanmar. Furthermore**,** the availability of hatchery-produced seed would reduce the need for wild fry collection, which is in most cases a destructive practice, and would contribute to conservation of the coastal fisheries resources.

Hatchery technologies should be developed through basic and applied research and testing in pilot projects. The technologies would include disease prevention and control, development of larval nutrition and feeds, and water quality management for a variety of species, particularly marine finfish,

Myanmar (in 2000) has seven shrimp hatcheries in operation. Four hatcheries (including three DOF backyard hatcheries and one Thai aided hatchery) are almost completed and about to start operations. However, without hatchery development by the private sector, it is still impossible to fulfill the increasing demand. More information on backyard hatcheries should be provided to the private sector.

There are no hatcheries for finfish, (grouper, milkfish and mullet). In order to enhance the development of finfish culture, Myanmar should urgently implement "Seed Supply and Hatchery Development Research for Marine Fish". National fishery agencies and research institutions working closely with the private sector could undertake this task. Regional coordination and facilitation through regional bodies, like NACA and SEAFDEC, would be beneficial. External expertise and learning from similar efforts may be necessary to implement national projects.

The following research work is needed to accelerate the development of marine fish aquaculture in Myanmar.

- Grouper (*Epinephelus* sp)
  - Fish health programs
  - Grow-out culture systems
  - Broodstock development and breeding techniques
  - Development of artificial feeds for nursery and grow-out
  - Development of rearing techniques for hatchery and nursery
  - Development of holding and transportation techniques for wild-caught fry and juveniles
- Seabass (*Lates calcarifer)*
  - Culture systems
  - Fish health programs
  - Broodstock management to control in-breeding
  - Development of artificial feeds and practical diets
- Mullet (*Mugil cephalus)*
  - Grow-out culture
  - Broodstock development
  - Development of restring techniques for hatchery and nursery
- Snapper (*Lutjanus argentimaculatus)*
  - Feed development
  - Broodstock development
  - Development of rearing techniques for hatchery, nursery and grow-out
- Mud crab (*Scylla serrata)*
  - Farming techniques (juvenile to market)
    - feeding
    - polyculture
    - culture in existing mangroves

- Broodstock and larval tearing techniques

- Slipper oyster (*Crassostrea* sp.)
  - Transplantation
  - Spatfall forecasting
  - Evaluation of culture technology
  - Refinement of grow-out techniques
  - Product development and other uses

- Seaweeds (*Gracilaria* sp.)
  - Bio-filters
  - Product use
  - Refine production methods
  - Monoculture and polyculture in ponds
  - Inventory of gracilaria species and selection and development of highly productive cultivars with high quality agar

Conclusion

Aquaculture in Myanmar seems to be limited to freshwater finfish and crustaceans. Presently, only one marine prawn species *(Penaeus monodon)* and one genus of marine fish *(Epinephelus* spp.*)* are successfully cultured commercially in the country.

The extensive brackishwaters, tidal estuaries and swamps that exist on the entire coast are sources for aquaculture. Most fish farms in Myanmar still practice traditional methods (trap and hold). This type of culture may lead to depletion of natural resources for some marine species. Because of low urbanization and industrialization in coastal areas, water pollution caused by chemical and industrial waste is negligible in Myanmar.

The government plans to expand both freshwater fish culture and marine fish culture in the coastal areas. Fish culture will create opportunities for employment and generate hard currency.

There are several promising species: seabass *(Lates calcarifer),* grouper *(Epinephelus* sp.*),* milkfish (*Chanos chanos)*, mullet *(Mugil cephalus)* snapper *(Lutjanus* sp.), mangrove crab (*Scylla serrata*), oysters *(Crassostrea* sp.*)* and seaweeds (*Gracilaria* sp.), which are indigenous and yield vary good market prices. In order to culture these marine and brackish water species, the following technologies are urgently required:

- Grow-out systems
- Fish-health programs
- Broodstock development and breeding techniques
- Development of artificial feeds for nursery and grow-out
- Development of rearing techniques for hatchery and nursery
- Related technologies (live-food culture technology, water quality management and disease control), and
- Development of holding and transportation techniques for wild caught fry and juveniles

In order to accelerate the development of aquaculture in Myanmar, organizations like SEAFDEC, KOICA, JICA, NACA provide training programmes in various fields, especially in freshwater fish aquaculture and brackish water fish aquaculture.

Myanmar is rich in marine fisheries resources and has high potential for mariculture**.** It should develop its fish, shrimp and other marine species farming industry for local consumption and export.

Grouper Aquaculture in the Philippines

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Abstract

This presentation provides information on grouper aquaculture in the Philippines. It reports on results of research in the Philippines on the use of mosquito fish as a possible alternative food for grouper, E. coioides*. Information on the natural spawning frequency of* E. coioides *is given. Results from proximate analyses of mosquito fish, tilapia and trash fish are also provided.*

Introduction

Among reef-fishes, grouper is still the preferred fish by small-scale fishfarmers, fisherman and export traders in the Philippines. It has a high demand both in domestic and export markets. Much of the supply is provided by capture fisheries and has encouraged the use of ecologically unsustainable fishing practices using cyanide. The trade of live grouper warranted the setting up of six Cyanide Detection Laboratories that now monitor, inspect and sample shipments.

Grouper aquaculture in brackishwater ponds and cages is still very popular although production remains insignificant compared to other aquaculture products because of insufficient supply of grouper seeds and high feeding cost. *Epinephelus coioides* is the most common species for aquaculture in the country and fry is obtained from the wild by trapping. The updated collection sites of fry and fingerlings all-over the country are being identified and collected by the Regional Offices of Bureau of Fisheries and Aquatic Resources, which begun operation in 1999.

Present Government Interventions

Recognizing the constraints of grouper culture in the country, the government started the construction of breeding facilities in Palawan under BFAR Reg. IV and Western Samar. Both projects, which started in 1999, are being assisted by SEAFDEC, Iloilo. Another project is under construction in Aurora Province in the Pacific Rim being assisted by BFAR-NIFTDC, Dagupan City. These three facilities will participate in the research and development programs of the government on grouper farming.

Breeding

The National Integrated Fisheries Technology Development Center based in Dagupan City is the only BFAR working on grouper production. Sever year old *E. coioides* breeders are used in the Center. Using 40T capacity tanks, it was able to prouduce eggs in May, June and August 1998 (see Table 1) with a total of 14 spawnings. Only the five *E. coioides* batches in June reached the post fingerling stage.

Table 1. Natural Spawning Frequency of Grouper (*E. coioides*) in 40T tanks at NIFTDC from 1998 to 1999

Year	Month	No. of Spawning	No. of batches reached post fingerling stage	Remarks
1998	May	1	-	90% of hatchery building roofings was blown off by 1998 typhoon
	June	5	5	
	August	8	-	
		14		
1999	Feb	11	1	
	March	8	-	
	April	9	-	
	May	6	1	
	June	8	-	
		42		

In 1999, the spawning started earlier in February and continued until June. A total of 42 spawnings were recorded. Unfortunately, no hatching activity was conducted since the facility was devastated by a supertyphoon in late November 1998 and remained disarray until the middle of 1999. Presently, the facility was repaired and prepared for Year 2000 activities. Spawning of grouper is now being awaited.

Culture

A major drawback in raising grouper is its dependence on trash fish as feeds. A question is raised on grouper competing with humans in the use of fishing by-catch, such as round scad (*Decapterus macrosoma*) and slipmouth (*Leognathus* sp.) as food. Due to this, the government is adamant to fully support grouper breeding studies.

Live-prey studies

The BFAR-NIFTDC embarked on conducting studies to utilize other fish species such as mosquito fish (Poeciliids) as possible alternative food for grouper. The concept of combined grouper – poecilla culture in ponds, with the latter as live prey, is being evaluated.

The Poeciliidae family consists of small and some colorful fishes used for aquarium or biological control of mosquitoes. They are prolific breeders and produce free-swimming young. Male Poeciliids use long pointed gonopodium to allow passage of packets of sperm into the females. These packets break up to release the sperm to fertilise the ripe eggs, while the remainders are stored in the oviduct for fertilization of successive broods.

Poeciliids inhabit brackish or coastal areas. They are found and multiply in canals or shallow pools with temperature higher than 32^{o}C.

Initial studies were conducted on the fecundity of Poeciliids in hapas. Eight fine-mesh hapa nets measuring 2 x 2 m, with an inner B-net hapa measuring 1 x 1 m installed inside the first hapa were used in a brackishwater pond of 25 ppt salinity. Sexually matured mosquito fish breeders of about 1 g average weight were stocked into the inner hapa. Fourteen breeders were stocked in the first set of four hapas at 1:1 ratio, while the second set of hapas were stocked with 15 breeders at 4f : 1m sex ratio. They were given no feeding during the experiment. After 30 days the fry and fingerlings produced in each hapa were counted.

The result of the experiment indicated that about 400 fingerlings measuring 1 cm to 2.5 cm can be produced from 15 breeders in a 1 x 1 breeding compartment in 30 days (see Table 2). The results indicate that higher female breeding population per unit area will result to better production. There are about 970 pcs. in one kilogram of mosquito fish. Furthermore, feeding may not be required to Poeciliieds during the breeding process.

Table 2. Fecundity of mosquito in 1 x 1 m hapa in 30 days

	Treatment 1				**Treatment 2**			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*
Total no. of breeders	15	15	15	15	14	14	14	14
Sex Ratio	4f:1m	4f:1m	4f:1m	4f:1m	1f:1m	1f:1m	1f:1m	1f:1m
No. Of fingerlings	258	391	465	475	117	390	259	145
After 30 Days								
Average production per hapa	397.25				227.75			
Average production per female breeder	33.1				32.54			

Experiments done earlier on the production of the live-prey done in fine-mesh hapas resulted to low production because of the outright cannibalism of the young by the breeders. A coarse hapa that will allow escape of fry and separate the young from the breeders was found to be necessary. The technique is applicable in grouper nursery ponds where Poeciliids can continuously by bred in coarse hapas and produce smaller live-prey.

Further study is currently being conducted using more females in breeding. Application in nursery ponds will be done when grouper fingerlings will be available.

Farming System Management

A recommended pond culture technique for grouper since 1985 is polyculture with tilapia at 15,000 – 20,000 tilapia per 1000 grouper per hectare. The system will decrease dependence on trashfish in raising grouper.

Providing live – prey to grouper may also lessen problems related to pond-water quality due to the use of dead trash fish. Use of live-prey may also increase the feeding frequency of grouper that may lead to a faster weight increase. The proximate compositions of Poeciliids, tilapia and trash fish (slip mouth, *Leograthus* sp.).

Table 3. Proximate composition of Poeciliids and trashfish

	Mosquito Fish	**Tilapia**	**Trashfish**
Protein	61.1	48.6	72.5
Fat	13.0	8.3	6.4
Fiber	0.2	0.2	0.2
Moisture	7.8	19.8	8.9
Ash	16.1	16.7	16.8
Nitrogen-free extract	1.8	6.4	-
Calcium	3.05	3.62	5.64
Phosphorus	2.40	2.84	3.30

An initial experiment was done to compare the effect of live prey, Poeciliids and tilapia and trash fish on water quality at BFAR-NIFTDC. Juvenile grouper with an average weight of 215 g were stocked in 12 100 l capacity rectangular plastic tanks filled with 50 l seawater (25 ppt) at a density of 1 fish per tank. Sufficient aeration and shelter (pipe) were provided. The grouper were conditioned for 48 h before the start of the experiment.

Live-prey (Poeciliids and tilapia) were collected from the wild. Separately, they were stocked in 500 l tanks. They were allowed to settle for 24 hours and fed with commercial feeds. They were gradually acclimatized from 8 ppt to 25 ppt over 96 h period. The weight biomass of Poeciliids, tilapia and chopped trashfish were the same at 100 g per tank. For evaluation purposes the size of live-prey was kept at about 1g each.

Four feeding treatments were applied: live tilapia; live mosquito fish; chopped trashfish; and live combined mosquito fish and tilapia. The amount of trash fish given per day is based on the average weight of live-preys divided by 10 days. There were three replicates for each treatment. Water quality parameters such as salinity, pH, dissolved oxygen, nitrite, phosphate and ammonia were monitored in all tanks daily. The behavior of the grouper was observed.

The investigation, which was done to test the soundness of the protocol, will be modified before the second experimental run. The investigators are still analyzing the results of the experiment. The preliminary results, however, indicated some positive insights on the use of Poeciliids as live prey for grouper.

During the experiment, there was no mortality in mosquito fish in all tanks while tilapia started dying in Day 2. Also, groupers in tanks 12 and 11, where combined mosquito fish and tilapia were used, died in Days 7 and 9, respectively. In tank 3, where tilapia was used, the grouper displayed moribund behavior starting at Day 8. Dissolved oxygen, temperature and salinity remained normal until Day 10. Among the four treatments mosquito fish gave the most acceptable values in such parameters as ammonia, nitrite and phosphate. However, when mosquito fish was combined with tilapia, water quality was adversely affected and led to the death of grouper in 2 tanks.

Re-runs of this experiment using an improved protocol will be conducted this year to elicit more information.

Perspectives

Inadequate supply of fry fingerlings and unavailability and high cost of trashfish are still the main constraints of grouper aquaculture in the Philippines. In addition, updated information on sources of wild grouper fingerlings and volume of grouper produced by aquaculture and fishing are absent. This year the volume of trade of grouper a revitalized Bureau of Fisheries and Aquatic Resources will determine fingerlings and food size fish in the country through its regional offices. Moreover, the volume of live-fish exported will be monitored through the Cyanide Detection Laboratories.

The improvement of larval techniques in breeding will be given more attention. Applied research on farming systems, which may lessen production cost of grouper, will continue to be undertaken. Participation in collaborative undertaking espoused by APEC-NACA, and other networking activities will be strengthened to facilitate growth of the grouper industry in the Philippines.

Grouper Aquaculture in Malaysia

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Abstract

The paper describes grouper aquaculture in Malaysia. Grouper production statistics are provided. Seed production and supply, the types of feed used and various culture systems adopted in Malaysia are also briefly discussed. The current strategies for grouper aquaculture development, problems associated with grouper aquaculture and future prospects of this industry are included. Brief information on Malaysian programmes for future development of grouper aquaculture is given as well.

Introduction

Seafarming in Malaysia began in the 1930s, and grouper culture started in Penang during the 1970s (Chuah et al. 1977) using floating net cages and seed. The culture is now practiced throughout the country. The major culture sites are on the west coast of Peninsular Malaysia, especially in Kukup (Johore), Pulau Ketam (Selangor), Sungai Udang (Penang) and Sungai Merbok (Kedah). These sites offer protection against strong currents, winds and waves (Leong, 1997).

Several species of groupers are raised in floating net cages in Malaysia. The major species are *Epinephalus coioides (*or *E. suillus), E. tauvina, E. fuscoguttatus, Plectropomus leopardus,* and *P. maculatus*. Other species includes *E. areolatus, E. bleekeri* and *Cromileptis altivelis.*

Wild seeds are the major source of the local supply. They are collected during breeding season, which coincides with the monsoon season, November to March. Imported seeds come mainly from Chinese Taipei while some are imported from Thailand. The Marine Finfish Production and Research Centre, Tanjung Demong, 22200 Besut, Terengganu, Malaysia (MFPRC) also produces some grouper seed. It is a government finfish fry production and research centre that succeeded in producing a variety of grouper seed. It performs production and research activities as well as provides training to local finfish hatchery operators. There are two main private hatcheries which can produce grouper seed in captivity. These hatcheries include Penshrimp hatchery in Penang and Eastern Marine Trading in Johore.

Culture of grouper in ponds started with the trapping pond system, where the wild seeds were trapped from the incoming water. The harvest from this system was low and unpredictable. With proper fry collection techniques and abundant supply of seed collected from the wild, fish farmers shifted to floating net cages. At present, this is the most popular system for marine fisnfish culture operation.

Grouper are usually cultured in floating net cages (3mx3mx2m) at a density of 500 fingerlings (7 cm to 10 cm) with a size grading every two to four weeks to improve survival rates (Leong, 1997). Though trash fish has been commonly used as feed, commercial pellet feed at 40% dietary protein level (Chua and Teng 1978, Teng et al. 1978) is recommended. It takes about eight months for the fingerlings to achieve market size (600 g to 800 g/piece) with a survival rate close to 50% (Leong 1997).

Present Status of Grouper Culture

About 1,779 fish farmers are involved in the marine finfsh culture industry. They use about 58,449 units of floating net cages on the water surface area of about 68 ha. Total production in 1997 was 5,619.58 mt valued at RM 100,286,070. This accounted for about 5% of total aquaculture production by weight and 16% by value. Seabass comprised about 49.5%, snappers 24.7%, groupers 14.2% and others 11.4% of the total cage production. New species like milk fish and red drum are being introduced for pond culture (Subramaniam et. al. 1996 and 1999).

Grouper Production

Grouper production was 798.42 mt with a value of RM 28,398,880. This accounted for 14.2% by weight and 28.3% by value of the total marine fish produced by the aquaculture industry in Malaysia. Most of the grouper production comes from floating net cages. Groupers were successfully cultured in ponds using commercial pellet feed by the Brackish Water Aquaculture Centre in Johore (Subramaniam 1998).

Seed Production and Supply

The total seed required for culture is about 40 million. About 15% of the seed is collected from the wild and/or produced locally in government or private marine finfish hatcheries. The rest (85%) is imported either from Chinese Taipei or Thailand.

A preliminary method for seed production has been developed for *E. coioides* (and/or *E. malabaricus*), *E. suillus* and *E. fuscoguttatus* by Doi *et.al*. (1991), Ali *et. al*.(1992) and Hussin *et. al*. (1996a).

Types of Feed

Minced or chopped trash fish has been used in grouper culture. Due to the dwindling supply of trash fish and its inherent low quality, a formulated diet is becoming more popular. Several private feed millers have produced suitable formulated diets for groupers. Some are in a powder form and should be mixed with minced trash fish; others are slow sinking pellets which are consumed by the fish directly. Though the formulated diets have their advantages in terms of their quality and consistency of supply, the high protein requirement of about 40% make formulated diets more expensive and force some farmers to substitute the feed with trash fish.

Culture Systems

The most popular culture system is the traditional floating net cage measuring 3mx3mx2m or 6mx6mx2m, with polyethelene nets, wooden frame and floats. These cages can only be used in coastal areas, bays, estuaries and lagoons that offer some protection against strong currents, winds and waves. Poor culture management practices in such areas could lead to disease problems and environmental degradation. The Department of Fisheries in Malaysia is introducing off-shore cages, which are larger and can withstand strong currents. The grow-out cages are round, measuring 16 m in diameter and 8 m in depth. The nursery cages are rectangular but smaller, measuring 6mx6mx3m. Several demonstration projects are being set up.

Future Prospects of Grouper Culture

Given the population growth and the increasing demand for fish (40 kg per capita in 1995 to 56 kg per capita [estimated] in 2010), the present production of about 6,000 mt is insufficient. Production must increase to 110,000 mt by the year 2010. There are a number of potential areas for seafarming in Malaysia. The government has provided support and incentives to expedite fish production. The future of marine finfish culture in Malaysia is strong.

Strategies for Grouper Culture Development

At the current rate of growth and use of traditional floating net cages, it will take thirty years before the country achieves the target production of 110,000 mt. To expedite marine finfish production and realize the target production, there is a need for a quantum leap to a culture system with higher production capacity. A new culture system, which could be used in open sea is being introduced in Malaysia.

There are few marine finfish hatcheries in the country and they cannot cope with the increasing demand for fingerlings. Efforts are being made to increase the number of hatcheries by tenfold by the year 2010. Another important area is development of healthy broodstock to ensure that fingerlings are pathogen-free. The objective is to increase production by increasing the survival rate.

Problems Associated with Grouper Culture

Maintenance of sufficient marine finfish broodstock, suitable techniques for fry production, adequate supply of fingerlings, low pollution diets and disease free seeds are the major constraints to the rapid development of grouper culture in Malaysia. Sufficient focus on these priority areas and greater support from the authorities will assist in resolving the constraints.

Programmes for Future Development of Grouper Culture

The Government of Malaysia has formulated several programmes that help address the main problems faced by the marine finfish culture industry. Suitable sites are to be selected for aquaculture zones, and adequate infrastructure is to be developed. The cage farmers are encouraged to implement good management practices in the designated aquaculture zones.

Research and development will focus on studies related to broodstock genetics, live feed production, fry production technology, formulation of low pollution diets and production of disease free seed.

A national task force on grouper aquaculture in Malaysia has been set up to expedite the research and development work on grouper culture. The committee is made up of research officers from the Department of Fisheries, senior researchers from the local universities, hatchery operators and fish farmers from the major farms. Five committees at the divisional level have been set up. The committees review the problems faced by the industry. The progress at the divisional level is reported to the national committee to formulate policies and provide direction.

Recommendation and Conclusion

Healthy and disease free grouper fingerling are the major constraint to the rapid development of the culture industry. More work is required on seed production and live food production techniques. Development of a good strain of healthy broodstock, which could produce specific pathogen-free fingerlings is highly recommended for the success of grouper culture in Malaysia. Regional assistance is required to implement the programme more effectively.

The present production of about 8.25 kg/m^2 is well below the production average of about 20 to 30 kg/m^2 per year achieved by cage farmers in more advanced countries (Ismail 1997). Open sea cages were introduced to increase fish production. In addition, attempts are being made to enforce good management practices in order to avoid disease problems. Use of healthy fingerling and low pollution diets are recommended to increase fish production to the level achieved by farmers in developed nations.

Work on diseases will focus on developing suitable vaccines for disease prevention and on collaborating with the genetic group to produce healthy fingerlings. Work on nutritional aspects should include incorporating locally available protein sources to reduce feed costs and formulate feeds with lower pollution levels.

Efforts are being made to develop additional marine finfish hatcheries in the country. The present number of twenty hatcheries and nurseries in the country need to be increased tenfold by 2010 to satisfy demand.

Some of the wild seed collected from Malaysian waters find their way abroad, while the nation itself has insufficient seed supply. Implementation of a closed season from November to December has enabled the collection of seeds of suitable size, which reduces mortality due to handling stress. Regulation on the ban on grouper fingerlings has enabled most of the wild caught fish seed find its way back into local cages.

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Development of New Artisanal Fisheries Based on the Capture and Culture of Postlarval Coral Reef Fish

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Abstract

This paper provides details of an ACIAR funded project on artisanal fisheries based on capture and culture of post-larval coral reef fish, it is a 3 year project that is carried out by ICLARM in Solomon Islands. The author provide details of the methodologies used for post-larval coral reef fish species such as light-traps and crest-nets, and details of the species caught by both methods.

Introduction

During the past decade, collection of tropical marine fish for the aquarium trade and harvesting of food fish for the live reef fish trade has expanded rapidly. In the Solomon Islands, people collect 150 species of aquarium fish from coastal villages for export, with about 40 species accounting for the majority of sales. The live reef fish trade (LRFT) is centred on relatively few high-value species transported live to Hong Kong, China, Chinese Taipei and China. The highest prices are commanded by *Cromileptes altivelis* (Family Serranidae) and *Cheilinus undulatus* (Family Labridae). A variety of groupers and snappers dominate catches *Epinephelus* and *Plectropomus* (Family Lutjanidae). Demand for live fish in both markets is expected to increase.

The live reef fish industry is important to coastal communities in developing countries of the South Pacific and Southeast Asia. Virtually every country in the region is involved in trading live coral reef fish. In some countries, however, the intense demand for coral reef fish has led to over fishing and the use of destructive fishing methods.

The development of new artisanal fisheries based on the capture and culture of post-larval coral reef fish is a 3-year ACIAR-funded project being undertaken by ICLARM in the Western Province of Solomon Islands. ICLARM is collaborating with Dr Peter Doherty of the Australian Institute of Marine Science (AIMS) and Ms Michelle Lam of the Fisheries Division, Ministry of Agriculture and Fisheries (MAF), Solomon Islands.

The project is based on catching a small proportion of the juvenile year-class (before they encounter severe predation), and then rearing them in captivity. The development of sustainable methods for the capture and culture of coral reef fishes depends on finding efficient ways to catch the juveniles before they suffer high levels of mortality and the development of cost-effective methods for rearing them to useful sizes. It will also depend on identifying safe levels of harvest to ensure that the removal of post-larvae does not adversely affect natural replenishment of stocks. The objectives of the project are to:

- Investigate temporal variation in availability of post-larval reef fish near Gizo in the Western Province of Solomon Islands over a 2.5 year period

- Compare the species composition of catches of post-larval fish in light-traps and crest-nets, and determine the effectiveness of the two techniques in providing juveniles fit for aquaculture, and
- Develop methods for village-based grow-out of selected species of post-larval reef fish

The research will concentrate on coral reef fish of value to the live reef fish trade. These include families of interest to the aquarium trade, for example, Chaetodontidae (butterflyfishes), Pomacanthidae (angelfishes), and Acanthuridae (surgeonfishes and tangs), and the genera *Plectropomus* and *Epinephelus* (family Serranidae).

Methodology

Post-larval coral reef fish are caught using two methods.

Light-traps

These traps are the standard traps used by AIMS. The design is simple. Essentially, a light-trap is a waterproof light unit (battery powered fluorescent tube) bolted inside a perspex box with funnels to allow fish entry but discourage exit. Due to the high likelihood of interference and/or theft, light-traps are "locked" to the seafloor. They are located at a set distance from the seafloor, and their proximity to the surface varies with tidal movement. Data presented in this paper are from four replicate light-traps set around the new moon period, for one night at each of six sites. The sites were tested this way for six months.

Results from the light traps are summarised below:

- Between May and October 1999; 36,441 fish belonging to 50 families were collected from 123 light-traps
- Clupeids (herrings) were the most frequently caught family. They accounted for 16,314 fish or 45% of the total catch. The next most frequently caught family was the Apogonidae with 7,462 fish or 20% of the total
- A total of 2,781 fish of value to the aquarium trade were recorded from 8 taxa, comprising 8% of the total catch. Approximately 93% of these fish (2,594) were from the family Pomacentridae (damselfish)
- There were few differences in catches from different months. In August, higher number of fish was caught and species were more diverse that in September and October

Crest-nets

Stationary crest-nets can capture large quantities of fish, including valuable species like groupers, and some small taxa not sampled well by light-traps. Crest-nets were set behind the surf zone of fringing barrier reefs to catch post-larvae crossing over to back-reef lagoons. Two nets were deployed on shallow reef crests with unidirectional wave action about a ten minute boat ride from Nusa Tupe. Data presented in this paper are from a single sampling session for a week in October. Sampling has continued for fourteen nights around the new moon every month since October and future papers will discuss more comprehensive crest-net data. The nets were cleared each morning and catch returned to the laboratory for sorting and identification. We use old nets with soft cod-ends, which are adequate for monitoring purposes but do not maximise live catch. Nevertheless, many fish survive in good condition. Once the time of peak catches is identified, stiff cod-ends in the shape of a cylinder will be fitted to ensure survival of captured fish.

Results from crest nets are set out below:

- A total of 5,427 fish belonging to 34 taxa were collected from four crest-nets during October. In addition, 3 squid, 11 octopus, 11 juvenile spiny lobster and 6 coral shrimp were recorded
- The family Labridae (wrasses) was the most frequently caught group, with 2,399 or 44% of the total. The next most frequently caught family was the Gobiidae with 831 or 15% of the total catch
- A total of 72 fish of value to the aquarium trade were recorded from 8 taxa, comprising 1.3% of the total catch

Post Capture Handling

Light-trap and crest-net samples were treated in the same way after retrieval. Catches were inspected for any valuable species. Depending on the catch and state of the sample, valuable live individuals were removed and placed in a separate container, or air was pumped into the sample to keep the fish alive. The live fish were transferred to land-based concrete raceways with flow-through seawater. The remaining catch (of dead and non-valuable fish) was sorted, and the fish were preserved in a 5% formaldehyde solution. All fish were identified to at least the family level (lower when possible and relevant). This report presents data at the family level.

Live Fish

Since July 1999, valuable post-larvae have been reared in concrete raceways with a flow-through seawater system. The results to culture fish varied, but were mostly successful. Culturing butterflyfishes (Family Chaetodontidae) was difficult. Most other families valuable to the aquarium trade were relatively easy to keep alive and grow. Samples of these fish were sent to Honiara to an aquarium fish exporter for a professional opinion on the suitability for sale to the aquarium trade (based on species, size and condition). The feedback was positive, although marketability, competition, freight costs and space will be constraints to selling some species. For example, one of the potentially valuable families is Pomacentridae (damselfishes). The demand for this family is well covered by cheap fish from the Philippines and it would not be profitable to export. However, with increasing pressure for the aquarium fish industry to promote "eco-labelling" (fish that have been captured in environmentally-friendly ways), this disadvantage may not persist.

A summary of the results of live fish rearing follows:

- More than 60 species belonging to 20 families were kept alive and fed in concrete raceways
- Most fish (with the exception of butterflyfishes) readily accepted inert food. The food used for fish included fish eggs (roe) from a variety of species, live rock, filtered plankton (caught at night using torch and filter), plankton that comes through the seawater pump, and prepared food supplied by Dr Mike Rimmer (QDPI, ACIAR Project FIS/97/93)

- Damselfish were the easiest to keep but they are not of high value to the aquarium trade. Butterflyfish were the most difficult to rear. Butterflyfish belong to higher value groups so there is an incentive to overcome difficulties in rearing
- Species of value to the aquarium or live reef fish trade were not common in samples from light-traps and crest-nets between May and October 1999. Some of the species of value were too small for successful grow-out, or were too fragile to remain alive
- There appeared to be potential for capture and culture of some novel species for the aquarium trade, such as juvenile spiny lobsters (Family Panuliridae) and cleaner shrimps (Family Palaemonidae). These species are well sampled by crest-nets and seem to be fairly easy to rear. Several small octopus were caught and there may be a market for them if the keeping is easy

Overview of Results

Overall, catches have been low compared to results of tests using the same or similar methods in Australia and French Polynesia. If catches continue to be too low to provide sufficient numbers of valuable live fish for experimental work, it will be necessary to identify other nearby sites. Actions related to low catches has been postponed until we have completed a full year of sampling.

Potential for and Prevention of Over Fishing

The fact that a high proportion of post-larvae perish soon after settling on a reef provides a strong incentive to use the juvenile fish in more productive ways. However, research is needed to identify the percentage that can be removed without jeopardizing natural rates of replenishment. For example, field studies to identify the distribution and mean quantity of post-larvae arriving on reefs, combined with data on the proportion surviving to adulthood, will enable managers to calculate the area of reef that should be protected from fishing for post-larvae to enable continual replenishment of wild stocks. Until the appropriate experiments are complete, conservative levels of harvest will be required. The easiest way to impose conservative levels of harvest is to restrict the amount of reef used for catching post-larvae. If over fishing appears to be a real threat, it could be regulated by introducing seasonal closures, rotational fishing of areas, limiting the number of fishers (or nets per fisher) and/or regulating the distance between nets.

Benefits of Research

For Solomon Islands and other developing countries in the Indo-Pacific, the research described in this proposal is expected to lead to the development of small-scale enterprises that could catch and culture wild fry of coral reef species of high value. This should create additional opportunities for villagers to derive income on a sustainable basis from inshore fisheries resources.

The research also has direct benefits for Australia. The data on seasonal variation in quantity of post-larvae in Solomon Islands can be compared with the extensive data on temporal and spatial variation in settlement of coral reef fish in Australia to determine whether the patterns in Australia are typical of the region. Regional variations in weather will also provide new information on possible links between climate and tropical fish stocks. Knowledge of the grow-out of juvenile reef fish should be of considerable value to ACIAR Project FIS/97/93, which will be concentrating on overcoming problems with the larval rearing of groupers and developing improved diets for growing-out the juveniles. This project may be able to identify which species of groupers and snappers are amenable to grow-out.

Hatchery Development Options for Marine Fish

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Abstract

This paper provides a detailed description of re-circulation hatchery system for marine finfish, with special reference to an experimental marine fish farm at Cua Lo in Vietnam. The marine farm is conducting experiments on Lates calcarifer*,* Pagrus major*,* Rachycentron canadum *and* Epinephelus *sp.*

Introduction

The consumption demand for marine fish is increasing which creates pressure on many fish populations over most of the world. Production of marine fish in captivity is an expanding industry. However, production of marine fish is facing many difficulties. One of the major constraints is the production of fry for grow-out. For many fish species the supply of fry is unstable and for some, reproduction is still unknown.

Even when reproduction is well studied, the production of fry can experience problems caused by diseases, improper nutrition and difficulties in management of hatcheries. This presentation will draw attention to the possibility of obtaining more control in hatcheries by advanced techniques such as re-circulation and intensification. This would allow production of more fry per tank volume.

Based on work with intensive hatcheries in Scandinavia, Chinese Taipei and Vietnam, it seems possible that the re-circulation hatchery can be successfully implemented in tropical and subtropical conditions. An intensive re-circulation hatchery should be adapted to local conditions and local fish species. Nevertheless, difficulties can occur in implementation of new production methods and strategies in another part of the world.

Re-circulation and intensification in a hatchery has advantages and disadvantages. Some advantages are:

- Low water consumption
- Stricter control at all levels
  - a. Water quality
  - b. Disease prevention
  - c. Reduced labour force
  - d. Discharge easier to control and treat
  - e. Feed distribution and its nutritive value
  - f. High output to volume (5 to 20 fry per liter)
- Control of most parameters allows production of marine fry of various species with different requirements if eggs are available

Disadvantages:

- The daily work consists of fixed procedures
- Re-circulation systems are more expensive to construct
- An intensive hatchery requires a stable supply of electricity
- The work in an intensive hatchery requires experienced people, and
- If diseases occur they can be very harmful due to the re-circulation

Many Asian countries are involved in extensive production of marine fish fry. Often different stages of fry production are carried out at different locations (broodstock rearing/egg production, larvae rearing in hatcheries and nursing up to a size suitable for release in net cages). Eggs and fry are distributed to farmers over a large area. Transporting fish around the country (and between countries) creates a risk for spreading diseases like viral nervous necrosis (VNN). VNN is probably the first severe disease discovered in tropical marine fish farming. It is very likely that more diseases will follow, as was the case in Europe during production development of salmonids.

Re-circulation at special farms that keep breeders and produce fry under strictly controlled conditions could help restrict spread of diseases. Such a farm should be kept isolated from all other fish production. They should contain disease free breeders (running control). They should never take any fish from outside. The breeders and fry should only be fed formulated diets. By use of re-circulation, consumption of water can be reduced, thereby facilitating treatment of the incoming water. During production of fry, selection of offspring as new breeders should take place. Thereby, it would be possibly to carry out a genetic selection based a number of parameters, which has been done with great success for many domesticated animals.

Re-circulation can be successfully used in:

- Hatcheries
- Stocking of breeders, and
- Nursery and fingerling production

The operating costs of growing-out most species to market size will still be too high to compete with fish produced in net cages It is important to keep in mind that a re-circulation hatchery or nursery does not result in more and higher quality fry by itself, but it can facilitate the work and provide opportunities to do what is best for the fish. In the end, it is the daily work and experience that will bring success.

Principles of Re-circulation

The methods of re-circulation in fish production are roughly the same no matter if it is used for hatcheries, nurseries or grow-out to market size. A number of different concepts exist on the market. I will briefly describe the concept I have used for many years for many marine fish with quite good results. Besides low water consumption, a significant advantage of re-circulation is conditioning of water. Use of biofilters stabilizes the quality of water in the tanks (water is mature). This stability occurs after a period ranging from several weeks to a few months and relies on the population of bacteria in the biofilters. This population of bacteria can be improved by use of commercially available products for inoculation of bacteria or by inoculation of bacteria from other biofilters. It seems that even marine fish larvae survive better in "mature" water rather than in crystal clear "immature" water.

Exchange of Water

It is important to distinguish between the external exchange of water, which is the amount of water added to the re-circulation system from outside, and the internal exchange of water, which is the exchange of water in the fish tanks inside the re-circulation system. The internal exchange of water is, of course, much larger than the external exchange.

Internal exchange of water

The water is loaded with faeces and hatcheries have uneaten live feed organisms. Therefore, mechanical filtration is applied to the water coming from the tanks. This filtration can range from swirl separators to filtration through screens with automatic backwash (expensive but efficient). If the density in the tanks is very low and it is not a hatchery, the mechanical filtration can be omitted because mature biofilters can degrade waste from the tanks.

After mechanical filtration water is collected in reservoir I. It is pumped into the bottom of the biofilters (two or more for safety). The biofilter is filled with a material that has a large specific surface. A plastic is frequently used as substrate. It is easy to work with, but expensive. I prefer the fixed substrate because of the quality of water they can produce but other suitable materials are available. In the biofilter, degradation of organic matter, together with oxidation of ammonia to nitrite takes place. If the biofilter is heavily loaded with organic matter, denitrification can occur, but this process can develop an extremely poisonous hydrogen sulphide and, therefore, should be controlled. Mainly, oxygen is consumed and carbon dioxide is produced.

Water leaving the top of the biofilter is passed to a trickling filter. Water is distributed evenly over the surface and floating in contact with air through the trickling filter. The trickling filter can consist of the same plastic material as used in the biofilter. In the trickling filter, some of the processes seen in the biofilter take place, but also an uptake of oxygen and release of carbon dioxide occur. After the trickling filter, water is collected in reservoir II. Reservoir II and reservoir I are connected but under normal operation water will not run between the two or will only run from reservoir II to reservoir I (determined by the placement of the pumps).

From reservoir II, water is pumped back to the fish tanks. It is possible to add pure oxygen through an oxygen cone (requires some pressure to be efficient), treat the water with UV radiation and/or ozone administration. The water can be pumped back to the tanks either by using two lines (one for aerated water and one for oxygenated water) or by using a single line where all water is supplied with oxygen

In the above description two sets of pumps are used, one for the biofilters and one for water supply to the fish tanks. It is also possible to reduce costs in smaller systems (especially hatcheries) by letting the water run to the tanks by gravity.

The external water comes filtered; it is added to reservoir II and leaves by overflow from reservoir I.

In general, the more intensive a system is, the more complicated and expensive it is because it will work within very narrow limits.

Experimental Marine Fish Farm at Cua Lo in Vietnam

Based on experience in Scandinavia and Asia, a land based experimental fish farm for production of marine finfish fry is under construction at Cua Lo near Vinh City, Vietnam. The design of the farm is combined with local experience and construction. The farm will produce fry for grow out at a small scale in net cages outside Cua Lo.

The land-based part of the farm will consist of the following:

- Filtration of seawater
- Reservoirs for seawater
- Tanks for breeders and spawning
- Nursery and fingerling system (re-circulation), and
- Hatchery and live feed cultures (partly placed in a building)

The purpose of this farm is to carry out an experimental production from breeder to market size fish of different marine species under controlled conditions. Actual species for this farm will be seabass (*Lates calcarifer*), red seabream (*Pagrus major*), cobia (*Rachycentron canadum*) and grouper (*Epinephelus* sp.)

Hatchery Building

The incubation, hatchery and live feed cultures will be placed in a building in order to provide stable conditions for these production processes. Air conditioners will be installed in some rooms. A sink, a table and supply of both fresh water and sea water will be placed in the rooms to ensure a high degree of hygiene and prevent transfer of culture organisms.

Incubation

After collection, the eggs will be transferred to the incubation tanks. They will be kept in tanks till hatching. During the incubation, un-fertilized and dead eggs will be separated. After hatching, the larvae will be transferred to the larvae tanks in the hatchery. The incubation consists of the following:

- 6 Cylindroconical tanks – 500 l

The incubation at full scale will use 10 m^3/day of 1 micron filtered seawater as a maximum. The incubation will only be used for a few days at a time.

Hatchery

After counting, the newly hatched larvae will be transferred from the incubation to the hatchery. The fish larvae will stay in the hatchery until metamorphosis (during the process of metamorphosis the fish larvae changes its appearance to an adult and after this change it is a fingerling). During most of the growth in the hatchery the preferred feed will be live feed. The hatchery is proposed as an intensive re-circulation system with its own water treatment system, including biofilter, UV treatment and mechanical filtration of water from the tanks. Each tank will be equipped with air supply for common aeration and surface skimming.

The hatchery will contain:

- 4 Cylindrical tanks - 2.0 m^3

- 8 Cylindrical tanks - 0.5 m^3

An air-conditioner will be installed in the hatchery room in order to control the temperature of the water.

Re-circulation technology in the hatchery will provide very stable water quality that is important for the health of the fish larvae. The circulation of water through the tanks inside the hatchery will be set to 12 m^3/hour as a maximum. The supply of one micron filtered water from outside to the hatchery system will be 0.5 to 3 m^3/day dependent on the density of fish.

The output from the hatchery depends on the species of fish. If, for example, the red seabream (*Pagrus major*) is produced, the output can reach 50,000 to 100,000 fry per batch.

Live Feed Cultures

The types of live feed used for rearing of marine fish larvae in this hatchery will be:

- Algae
- *Artemia*
- Rotifers, and
- Copepods

In general, live feed will be cultured under controlled conditions in seawater filtered to 1 μ or less. Except algae, live feed will be cultured in separate rooms to avoid mixing different cultures. Mixing of cultures in the worst case scenario may result in the need to discard part of the cultures, sterilize the culture facilities and initiate new cultures. This could delay the production of larvae by almost a month.

Continuous Algae

Algae are used as feed for the rotifer cultures. Algae will be used directly in the hatchery in the cylindrical larvae tanks when rearing certain fish species, for example, the red seabream. Several species of algae can be cultured, as different algae species are used for different purposes in the larvae rearing process.

- 6 Continuous flask cultures - 20 – 80 l (Daily harvest: 8 – 25 l)
- 40 unsterile plastic bag cultures - 2 m^3 (Daily harvest: 1 m^3)

Algae will be cultured continuously under sterile conditions in up to six separate flask cultures. Every day a maximum 25 litres of sterile algae culture will be harvested depending on the demand. These will be used as inoculation for further culturing outdoors. This culturing will take place in plastic bags under daylight.

Outdoor Algae

The outdoor plastic bag cultures are filled with 1 μ filtrated water, nutrients and aeration. Influenced by the strong light algae grow fast in the bag cultures. Algae can be harvested from the bags four to five days later and used as feed.

Copepods

In this hatchery, experiments are focused on hapacticoid copepods. Hapacticoid copepods can be cultured under controlled conditions in cylindrical tanks containing material from biofilters. The copepod nauplii and metanauplii with a size of 50 to120 microns are optimal as first feed for many small marine fish larvae such as groupers. For marine species with larger larvae, copepods are excellent as supplement to rotifers. The copepods are fed with algae and bakers yeast. Copepods will be cultured in cylindrical tanks.

Rotifers

Normally, the size of rotifers ranges from 100µ to 180µ depending on the strain. Rotifers eat by filtering particles from the surrounding seawater. They can be cultivated at very high densities (400 to 800 individuals/ml) and are an easy to produce initial feed for a number of marine fish species.

Starved rotifers do not contain the right composition of nutrients for marine fish larvae. Enrichment of the rotifers (feeding over four to six hours or long term enrichment) is recommend. During enrichment the rotifers are given food of high value for the fish larvae. These feed items could be algae and particularly polyunsaturated fatty acids descended from marine organisms. The enrichment is conducted during filtration of algae and oil drops from the water by the rotifer. Maintenance feeding of the rotifer cultures is mainly done by yeast.

Artemia

Artemia is a brine shrimp living in lakes of high salinity. *Artemia* eggs can withstand drying for long periods. This is used in the rearing technology. *Artemia* eggs (cysts) are collected in seawater lakes, dried, vacuum packed and sold canned. When *Artemia* is used for feed purposes, the required number of cysts are poured into warm seawater and kept under heavy aeration for about twenty-four hours. During this period the cysts hatch; the newly hatched *Artemia* nauplii can be used for feeding purposes.

These nauplii have a size around 450µ, depending on the strain. They are not suitable as initial feed for marine fish larvae. Furthermore, most of the newly hatched *Artemia* nauplii are deficient in vital polyunsaturated fatty acids. To compensate for these deficiencies, the newly hatched nauplii can be placed for twelve to twenty-four hours in seawater with an admixture of emulsified marine fish oil. The nauplii eat this oil; nauplii that have eaten the oil can be used as feed for marine fish larvae with reasonable results. Due to the size of the nauplii, they are normally not used until four to twelve days of feeding with rotifers.

Artemia will be cultured in cylindrical tanks. For culture, the following tanks are chosen.

- 6 small and 4 large tanks for culturing copepods - 40 l and 500 l tanks
- 10 tanks for culturing rotifers - 500 l tanks
- 10 tanks for hatching and enrichment of Artemia - 500 l tanks

Each room will be also supplied with 1µ filtered seawater. The maximum use of water is estimated at 8 m^3/day.

Laboratory

A small laboratory is placed close to the hatchery. The laboratory should contain a cooler, cooking plates and equipment such as a microscope, weight, refractrometer, oxygen meter and pH meter. The laboratory will be used as the base for controlling the larvae and live feed. In addition, it will be used as storage for chemical components and other items used in the daily production.

Nursery Tanks

After the metamorphosis (which will take place in the hatchery), the fish fry at the size of 30 mg to 40 mg will be transferred from the hatchery to nursery tanks. In the nursery tanks the fry are adapted to eating chopped fish or, if available, to eating dry feed. It will be advantageous to use feeding automates for weaning the fry to an inert diet in the nursery.

The nursery tanks has the following sizes:

- 4 composite tanks - 2 x 2 x 0.6 m^3
- 8 composite tanks - 1 x 1 x 0.4 m^3

The nursery tanks are supplied with water directly from the sand filter in order to give the fish fry optimal conditions. Aeration is installed in each tank by means of airstones. The total volumes of the nursery tanks are 10 m^3 and the maximum use of water is calculated to 10 m^3/h. The maximum density is set to 1 kg/m^3.

Fingerling Tanks

After reaching a size of 0.2 g the fish fry are transferred to the fingerling tanks. During the following period, it is necessary to conduct frequent grading of the fry to gain the best growth and lowest loss. After reaching a size of 5 g to 10 g, they can be transferred to net cages in the sea.

The fingerling tanks consists of the following units:

- 10 concrete tanks - 3 x 3 x 1.5 m^3

The fingerling tanks are part of the re-circulation system shown. This system is supplied with sand filtered sea water for external exchange of water. In order to improve the density of fish in the tanks, water led to the tanks can be boosted with a small amount of pure oxygen through an oxygen cone. The total volume of the fingerling tanks is 100 m^3. The maximum internal exchange of water of the fingerling system is 100 m^3/hour. The external exchange of water will range from 0.5 to 5 m^3/h. The maximum density of fish is set to 5 kg/m^3.

Broodstock

Outside the spawning period, the broodstock will be kept in net cages. During this period it is important to provide high quality feed in order to obtain the optimum quality of eggs. Fish feed should mainly consist of a formulated dry feed and/or high quality trash fish.

At the onset of the spawning season, fertile fish will be transferred to the broodstock tanks, eventually for treatment with hormones. Tanks with a volume of 10 m^3 are built in order to facilitate the handling of breeders during treatment with hormones. Larger tanks of 70 m^3 are built as spawning tanks. The following tanks form part of the broodstock system:

- 4 Concrete tanks - 6 x 6 x 2 m^3
- 4 Concrete tanks - 3 x 3 x 1.5 m^3

All tanks are equipped with external reservoirs with airlift pumps and collecting nets, which facilitates collection of eggs.

The water consumption for the broodstock system is estimated at 18 m^3 per hour, if all tanks are in use. Normally, only a few tanks at a time will be holding fish during the spawning season. The outlets from the tanks should be connected to the open drain.

Water Supply

The coast near the farm is sandy. However, due to effluent from a nearby river, sea water contains clay particles. Therefore, seawater could not be filtrated through the sand on the beach. Instead, water will be pumped to the farm, and stored in two reservoirs, placed at the north-east part of the farm. These reservoirs, each containing about 250 m^3, will act as coarse traps for sediment. A roof will cover them in order to avoid growth of algae.

From the reservoirs, water can be pumped to the broodstock tanks without filtration and a sand filter for further filtration. After filtration through the sand filter, the water is stored in a reservoir near the sand filter. This reservoir is also covered to avoid algae growth. The water filtered through sand is pumped to the nursery tanks, re-circulation fingerling system, and to the hatchery building for further filtration. The hatchery building and the live feed cultures required 1µ filtered water. Water is filtered through cartridge filters, which are quite expensive. The pre-filtration through sand will considerably extend the lifetime of the cartridge filters.

After use in production, the water is collected in open drains leading to a reservoir. From the reservoir, it is discarded into the sea either by gravity or by pumping.

The described hatchery is a part of an advanced capacity building program at Research Institute for Aquaculture No 1 (RIA No 1) Hanoi. The capacity building is supported by the Norwegian Agency for Development Co-operation (NORAD). The program consists of five components:

- Genetics
- Education
- Administration
- Disease control, and
- Marine fish farming

The construction of the marine facility at Cua Lo is supported by the Government of Vietnam. NORAD provides funds for most of the equipment in the hatchery.

Perspective on Future Directions in Cage Culture Related to Asia

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Abstract

This paper includes some lessons learned from working in Vietnam, Malaysia, Chinese Taipei, Indonesia and Norway. Government policies can have different development objectives, but there are not any significant differences. This means that people in research and development face the challenge of serving the needs of today and tomorrow. There are many preconceived notions about marine cage aquaculture, including whether it is an opportunity for a better livelihood for the poor or the rich. Some observations will be presented. Policymakers and donors have neglected these matters. This paper covers possible trends in development of marine aquaculture.

Background – Perception of Marine Aquaculture in Relation to Sustainability

When farmers start marine cage culture, they try to make a living from an available resource regardless of being landless fisher families or company owners.

Aid policies often consider two main modes of production – the subsistence and market demand production. Subsistence production includes farming of freshwater fish, while the market production includes seaweed, shrimp, clams and cockles, and marine fish in brackish and marine water areas. There is a perception that subsistence production is more sustainable (more suitable than the other) and it deserves support. The grouping into production modes and perception of sustainability, however, is too simplified, as it does not pay enough attention to the "development maturity" of the production.

It is too simple to view production of freshwater fish as targeting the immediate subsistence needs of increasing the nutritional level within the local farmer household. The households will, whenever possible, use production to increase their income by selling the production on the market. Therefore, the differentiation in production modes is often artificial. There is one common driving force regardless of the aquaculture type, and that is that the households want to improve their livelihood.

The type of production and technology will vary depending on resources available to the household (whether situated in coastal or inland communities). Sustainability is not related to the production mode but to maturity of development (whether the appropriate technologies have been developed and implemented).

The historical development context can be considered in a case study from Vietnam:

Before the introduction of the foreign carps in the 1960s and 1980s and simultaneous introduction of hatchery technology, fish production in rural inland areas was from inland capture fisheries and to a lesser extent from farming wild captured fry of many native species. The increased need for food generation together with these practices led to depletion of the inland fish resources and diminished biodiversity. It was not sustainable. At the present time, freshwater aquaculture involves intensive hatchery (transport of fry over large distances) and production to market demand, and it is still considered sustainable (which it should be).

In many countries in the region, the development of marine fish farming is at the same stage as freshwater fish farming nearly half a century ago in Vietnam. Marine aquaculture may be even more constrained due to lack of grow-out techniques, challenges in hatching of marine fish and farming the restricted inshore areas. As a result, marine-farmed fish production is generally still low and has not increased considerably over the last years. It is strange for an outside observer that marine farmed fish output from Asia is not significant, while otherwise it is the leading aquaculture region.

The opportunity to use marine fish farming as a means for livelihood improvement is seriously constrained by the lack of appropriate technologies. Fish farmers are trapped into using non-sustainable practices. The use of wild fry (or lack of hatchery produced fry) put stress on the recruitment of fish for capture fisheries and even on biodiversity. There is shortage of fry of the most popular species. The use of trash fish as feed constrains production as well as having a negative impact on the environment. Finally, the traditional cage technology forces the farms to cluster in very protected areas. This eventually leads to serious negative environmental impact. Other production constraints include diseases and low growth due to non-suitable water quality (high level of suspended material, freshwater impact from rivers and limiting oxygen content).

The shortage of fry and suitable areas for farming using the present farming technologies and practices leaves the livelihood potential untapped or unavailable for newcomers, despite the huge and increasing need for producing seafood and for improving or developing alternative livelihoods in the coastal zone in many countries. It is especially needed by the landless inshore fisher families, who are forced away from fisheries due to depletion of inshore stocks. The development of offshore fisheries can absorb only a fraction of the inshore fishers. Being landless, these people have very few ways to diversify their livelihood.

Several development plans or strategies exist, which can assist farmers entering marine aquaculture in new areas, protect the production of the existing farmers and protect the environment. Even if much needed restrictive planning within the present vulnerable farming areas were conducted, the huge pressure for finding a new livelihood would seriously threaten it. Its implementation would not be realistic, if no other farming alternatives (areas) could be suggested. This is why the term “entrapment” is descriptive for the situation of the present fish farmers, jobless and landless fisher families.

There is an immediate need for marine fish farming technologies that will improve farming practices and allow expansion into new, less vulnerable areas in the marine coastal region. However, the institutes responsible for developing the technologies do not have the capacity or governments have not yet focused on this issue.

Appropriate Technologies

The lack of available technology (including cost) is considered as the main obstacle to use of resources. This includes difficulties in procurement of marine fish fry, feed availability, disease problems and identifying technically (investment and physical) feasible farming structures to use the less protected parts of the inshore regions.

The lack of technologies or their cost partly prevents newcomers (the jobless and landless fisher families) to exploit this livelihood opportunity, and it has forced existing farmers to take shortcuts (collecting and keeping wild fry) in competition with capture fisheries for stocking material. The capture fisheries often benefit from aquaculture only by developing better logistics and marketing of live high value fish like the groupers. Often very limited value is added to the product through a growth of the fish biomass (or at least this accounts for maybe 25% to 30% of the price gain). Very little effort has been put into development of appropriate technologies. The shortage of technologies causes environmental problems, diseases and low growth. Inefficient production can only be feasible if it targets very high value products.

It is understandable that farmers target high value products. However, governments and institutes have to develop a more focused approach to identifying and developing the appropriate strategic technologies. The term "appropriate" means that first the need should be identified and then how to do it.

The need has two sides: the market need and the socio-economic need (the need for livelihood). The market has to be there first (or at least the potential market). This turns on a warning signal for the future of grouper farming.

Asia is focused on the lucrative live fish market. Again, this is understandable for individual farmers. This is the immediate market, where they can sell at a price that covers the costs of the current production methods. The postulate presented here is that wholesalers control this immediate market and they have an exorbitant profit margin. It is neither decided by the farmer nor the market potential.

At present, farmers in emerging marine farming regions focus on the grouper and so does the R&D sector due to the immediate and challenging needs to make grouper culture sustainable. However, the grouper market volume is actually small and very volatile due to the high exclusivity of the product.

Sudari Pawiro, INFOFISH. describes the grouper market in more detail but the overall production may be at a level of 15,000 mt and the main export market is Hong Kong, China which only imports around 5,000 mt. From a regional perspective, this is a very limited market. This explains the prices achieved but also gives an indication of its volatility and possible price collapse if production success is achieved. It is questionable, even if millions of dollars are used in grouper research, whether it will be easy to introduce appropriate practices and bring down the production costs of the aquaculture so that grouper farming becomes sustainable. It is possible that focus should be shifted toward aquaculture of other species, which show higher potential for increased production efficiency.

A case study for a "mature" market and production development of aquaculture

The following is a background presentation of an experienced market and production development. It will cover salmon production of Norway. Another example could be development of seabass and bream aquaculture in the Mediterranean Sea, which now has reached approximately 70,000 mt

Norway may seem to be an inappropriate example but it has to be understood that Norway was one of the poorest countries in Europe during the first half of the last century and that fish farming developed into an industry of national importance in less than 20 years. No traditions existed for fish farming, but there was a cultural tradition to build on. The base include the coastal villages' dependence on the fishery, as well as political and civil pressure to keep or enhance the income base or livelihood of the people living in the remote coastal regions.

The "dispersal of settling" has been an established policy in Norway for many decades. This policy resulted from Norway historically being a primary producer and from a political wish to keep people dispersed along the coast. The policy facilitated the development of fish farming.

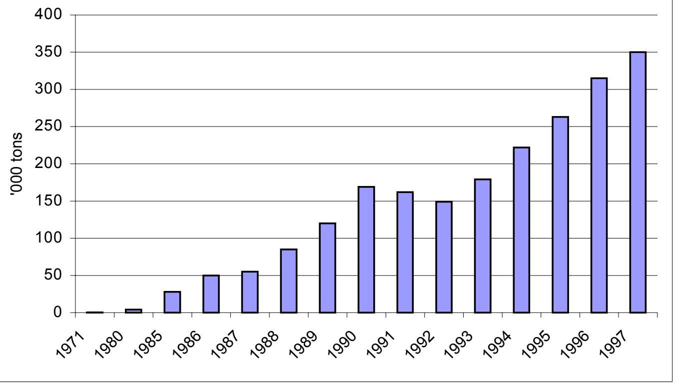
Fish farming started in the early 1960s by copying the land-based freshwater farming of plate-sized rainbow trout from Denmark, where it had been developing since the turn of the century. The land-based production never succeeded in Norway. Some of the pioneers started production of trout and later salmon in primitive cages in seawater in the late 1960s. Basically, these entrepreneurs were fishers but soon the idea was taken up by the "fisher peasants", (coastal agriculture farmers who used seasonal fishing on fish migrating in front of their coast line to supplement their income from farming activities on the poor mountainous fields). Then supportive R&D activities were actually started.

Market Development

The market development has been complicated but has shown large flexibility (forced by the market). It is reflected by the production volumes in Figure 1. It would not be possible to sell the present large production volume of salmon at the world market without intensive marketing. In the early period of salmon marketing, it mainly targeted countries which had traditions for salmone products. As the Atlantic salmon was considered a better product than other salmonids, and there was a lack of wild caught Atlantic salmon, the farmed salmon became an exclusive high value product. This market segment became fully saturated in Europe and the US (because of an anti-dumping tax), and in 1991 the fish farmers cooperative sales organization (FOS) faced a crisis. The prices had to be lowered considerably to sell the increasing farmed volumes. The structure surrounding FOS was too rigid; it was not able to accommodate the necessary shifts in pricing and marketing strategy because of a guaranteed minimum price to the farmer. The generic marketing was further improved to convince the main market in Europe to accept salmon as a medium priced commodity product and to introduce salmon to the Asian region as a high value fish. This provided the market for much larger volume. Of course, if the increased efficiency and lower production costs had not been achieved concurrently, this generic marketing strategy would not have been successful.

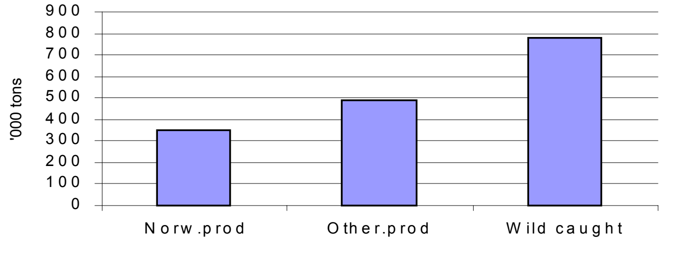
The main constraint to the growth of salmon production during the last years was the government imposed feed quota within farming of salmon. The reason of imposing a feed quota was the threat from EU to put an anti-dumping tax on imported salmon from Norway to protect Scottish salmon production. Norway had to promise EU (which imports 81% of the Norwegian production) to keep export growth at a maximum annual rate of 10% for a 5-year period. There is very strong generic marketing of salmon in Asia at present. Sales are expected to be 105,000 mt by 2002.

Figure 1: Production of salmon and trout in sea cages in Norway



The global role of Norwegian salmonid farming is illustrated in Figure 2. In 1997 Norway supplied 22% of the world consumption of salmonids from all sources – or 42% of the world farmed salmonids.

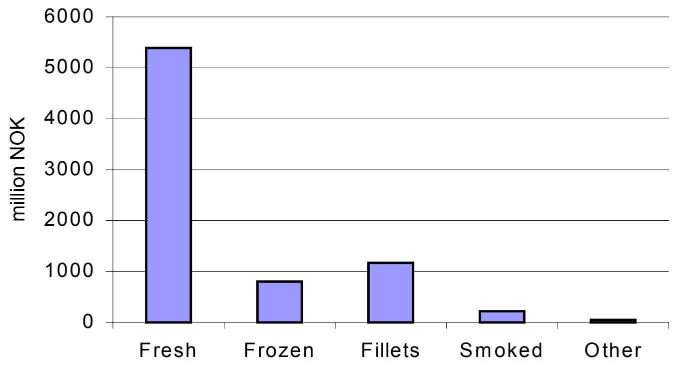
Figure 2: Global salmonids production from capture fisheries and aquaculture 1997



In 1997, the market value of salmon and trout export was one billion USD. Together with capture fisheries (US$ 2 billion), it was the second most important export item next to oil and gas even though Norway is among the largest oil exporters in the world.

Salmon is marketed worldwide as fresh/chilled salmon (Figure 3). This is partially because of the nature of the salmon product and the market (EU has a tax on processed salmon). However, it should be taken into consideration for possible development of market segments for Asian farmed marine products.

Figure 3: 1997-value of Norwegian salmon export by category



Business Structure and Employment Development

As mentioned earlier, the first entrepreneurs in fish farming were fishers. They were followed up by the "fisher peasants", (agro-farmers of the coastal region), who supplemented farm activities with seasonal fishing. As understanding and appreciation of the complexity of fish farming increased, many regional vocational fish farming schools started; and the staff of the fish farms became skilled and efficient in farming procedures. However, many farm owners were peasants/family businesses that lacked the skills of running the farm companies. Their economic and operational resources were too limited to overcome the constraints and they became highly dependent on bank (and feed company) financing.

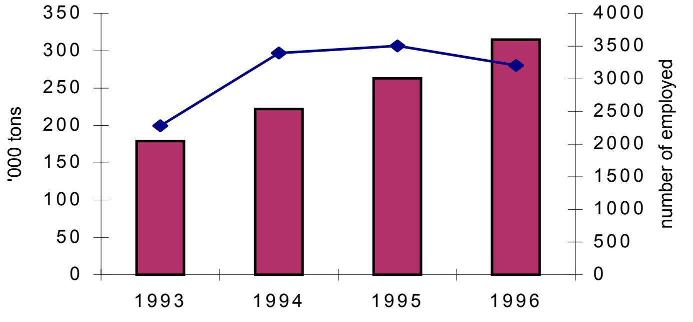
For a period, the banks (or regional development funds) gave easy credit to farmers. When the production volume of salmon hit the market ceiling, the farmers were guaranteed a minimum price from their cooperative sales organization - FOS. FOS decided to buy salmon at guaranteed prices to take it "out of market", and thus very large volumes of salmon had to be stored in cold stores (close to 50,000 mt). At one time all the Danish cold stores were occupied by Norwegian salmon. Eventually, FOS went bankrupt. So did a large number of farmers and several banks.

At this time there were perhaps 1,100 fish farm family-companies, each holding one concession. During the "progressive period" when the industry was growing, several large companies had also got interested in fish farming as a means of diversification. The government tried to limit companies' rights to hold several concessions as a part of the government social-democratic vision and because it viewed these processes as a threat to their policy of "dispersal of settling". When the business structure collapsed and the marketing of salmon experienced severe problems due to the lack of FOS and the "salmon mountain" in the cold stores, some of the large companies saw an opportunity for them to make use of their economic resources and experience in logistics. In 1991, large companies were allowed to hold several concessions. During and after the crisis the companies bought most concessions. At the present time, 180 companies are running the Norwegian fish farming industry; some of these are also engaged in salmon farming in Scotland, Ireland, Canada and Chile. Some of these large companies produce up to 70,000 mt of salmon/year.

The employment and economical effects of this change in business structure on the local communities were not negative as feared by the politicians. Skilled people from the small farms continued to be employed after the larger company took over the concession for a farm site, thus, the entry of the larger companies resulted in consolidation of the fish farming in the regions.

It is worth noting that the growth in production volume is not reflected in the number of employed people (Figure 4).

Figure 4: Relation between number of employed and production volume in the Norwegian salmon farming industry



The employment of 3,000 to 3,500 may seem as a small number but in a country of less than 5 million this is quite important. In addition, the derived employment in the remote sparsely populated regions is crucial for the survival of the coastal societies. Typically for every one person working on the farm, another three jobs are created in related services. The importance and attractiveness of aquaculture can also be seen in its winning competition over a fishery, which now sometimes faces problems in recruiting people.

Technology Development

Norway has supported the technological developments within fish farming very strongly. Norway focused its development work not only on biological matters but also on "technology development".

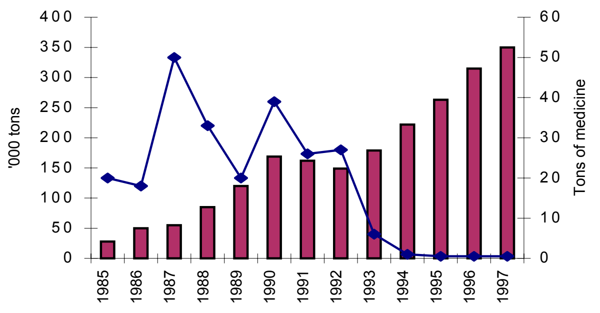
An annual average governmental funding of NOK 250 million (about US$ 30 million) has been supporting the aquaculture research and development in Norway until recently. Presently, funding is more limited and biological issues are given a high priority.

The technological priorities were:

- Disease prevention
- Feed development (on average the use of 1.1 kg of feed produces 1 kg of fish meat
- Domestication of the salmon (genetic program for quality, growth and feed conversion
- Cage development (cages which suit the needs of the fish and provide efficient working places for the farm worker

- Full control over the production of fingerlings (ability to control the maturing of the young salmon (smolt) to enter sea water)
- At the early stage, a feasibility study always included a production loss/mortality of 20% (to be on the safe side). Now the loss is down to almost 0%, apart from losses due to "mechanical" accidents, and
- Market image problem. Norwegian fish farming was getting a very bad reputation because of a high use of antibiotics leading to an associated pollution of the environment and the development of resistance problems. The use of antibiotics got out of control (Figure 5) during two major disease outbreaks in 1987 and 1990

Figure 5: Development of use of antibiotics in relation to production volume of Norwegian salmon



A disease prevention strategy was developed. The strategy identified all critical points in the farming procedures. Regulations have been introduced regarding fish farming management procedures, for example, it is now illegal to stock a fish cage with salmon smolt (fry), which are not vaccinated, and the smolt has to be produced in a hatchery from the region of the farm concession.

Effects of the Technology Development

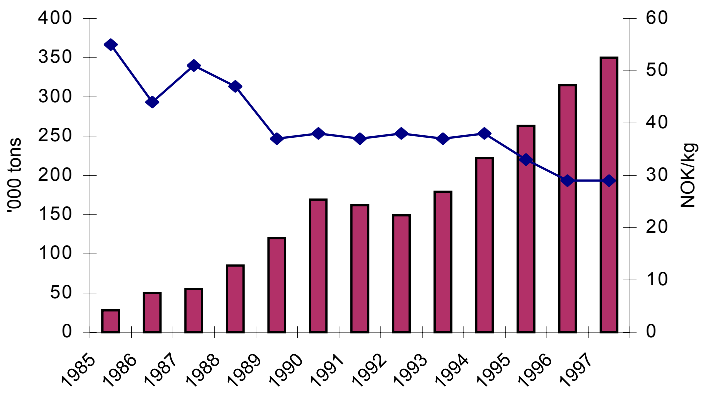
In the context of the historical development, the main outcomes of the technology development are the increased volume and increased efficiency (the lower is production cost, the higher value-added). Figure 6 shows that from 1985 to 1995 the ex-farm price has dropped from NOK 55 (US$ 1 = NOK 8.5) to NOK 33/kg. During the same time the production cost fell from estimated NOK 35 to NOK 19/kg.

This meant a drop in profit from NOK 22 to NOK 16 per kg of fish during the period. This is not so bad when looking at the profit margin against production cost. This increased from 63% to 84%, and at the same time the production volume increased more than 800%.

Asian Marine Fish Market and Scenario for Market Development

Traditionally, the products from farming and from capture fisheries have different market segments due to quality issues, especially those related to logistics. This means that aquaculture products always will target the high value segments. Some politicians and planners in countries like Vietnam, Malaysia and Norway see a potential for adding value to the farmed fish through processing. However, value-added processes are carried out to raise the value of cheaper, sometimes even inferior quality products from fisheries. This is not possible if the product already has high value. Nevertheless, if the high value market segment is saturated, and production costs of the high quality product has decreased, this may open the possibility to enter new market segments and get larger market volumes.

Figure 6: Development of price in relation to production volume of Norwegian salmon



Farmed Fish

Farmed seabass or snappers are usually traded in live form. This is due to the high farming costs and high demand for the fish. However, a small quantity is also marketed in fresh or chilled form through the retail sector. The latter is more applicable to farmed seabass than farmed red snapper. Processed products such as fillets in both fresh and frozen forms are almost non-existent in the market.

Landings from the Sea

Landings of fresh sea bass in the region are rather limited. Hence, most of the fish is usually sold in whole fresh or chilled form at a good price. Snappers are traded in the international markets in fresh or chilled and frozen forms as well as whole and filleted. Wild caught snappers are more abundant and cheaper. This means that the market segments and the role of the core products of the emerging farmed marine fish industry would be:

The Live Fish Market Segment

The live fish market segment is the immediate target market of farmed marine fish. Fish sizes are typically from 600 g to 700 g. The market volume is large, however, it still is limited compared to other segments as the product in not an easy commodity to handle. Most of the buyers would be from catering services. A larger share of this segment could be gained by increasing control of the export market and by increasing the competitiveness through improved logistics, consistent quality and lower production costs (all achieved by implementing new technologies). Those benefiting from this segment at present are the wholesalers, both in country of origin and in the importing country. For example, the present price in the Hong Kong, China market for live snapper is from RM 24 to RM 34, price of a wholesaler in Malaysia is RM 12.40 and the farm gate price is RM 8.25

Fresh or Chilled Market Segment

Marine farmed fish is only starting to enter this segment as the live fish market is more lucrative and competition in the fresh or chilled market from capture fisheries is stronger. Fish varies from 600 g to 700 g to even larger sizes. In view of farmed marine fish in the rest of the world, this segment is the most important. The decreased production costs will open this segment, especially that of the "small-sized fish" sub-segment. Capture fisheries will keep the "large-sized fish" sub-segment as this product is generally too expensive to produce in aquaculture (as seen in the Mediterranean area). The difference between the ex-farm price (RM8.26) and the market price for fresh or chilled fish from capture fisheries (RM10 to RM11) is small. It should be possible to reach a lower farm gate price through increased efficiency. Keeping sufficient profit margin for wholesalers, which are more numerous in the fresh markets (Table 4 and 5), would entice them to compete with capture fisheries. In the medium term the fresh or chilled segment will become the most important market segment of the marine farmed fish due to the increasing development of the supermarkets. This segment will open a high volume world market for the products.

Fillet (and Cutlet) Market Segment

In general, this segment is dominated world wide by landings from capture fisheries. Due to high processing losses, fish should be of large size, and the raw fish quality is not crucial for the final product. The production costs of the farmed fish may eventually become sufficiently low to become a resource for the fillet market segment in a sub-segment "for superior quality" fillets. However, the fish would have to be grown up to larger sizes (3 kg) and due to slower growth performance (poor feed conversion) of larger fish, this is not envisaged to become a large segment for farmed marine fish. Other conditions will have to be in place, including a decreased or restricted output from capture fisheries and a growing demand for quality white fish fillets. This trend is already present; the question is whether other more competitive aquaculture products will fill this market gap (fillets of tilapia).

The catch/farmed market volumes:

The following description will only briefly discuss seabass and snappers as they have the potential to be the core products in farming.

Seabass

In 1997, the world production of farmed seabass was 19,676 mt. The main producers were Chinese Taipei, Indonesia, Thailand and Malaysia. No figures of total regional landings have been available.

Snappers

Snappers are a rather large species group that supports a very large fishery. In 1997, the global landings of all species of snappers were around 190,000 mt. Based on FAO statistics, in 1997 about 2,128 mt were farmed, of which Malaysia produced 78%. However, the data does not include Thailand, Indonesia and the Philippines.

Table 1. World production (mt) of farmed seabass, 1993-1997

Country	1993	1994	1995	1996	1997
Australia	219	312	258	596	510
Brunei	26	51	74	72	69
Chinese Taipei	10,035	8,783	10,136	6,981	5,673
Hong Kong	211	210	207	144	72
Fr. Polynesia	6	-	3	10	2
Indonesia	2,622	2,381	1,815	4,401	5,400
Malaysia	3,865	2,691	2,206	2,365	3,487
Philippines	14	3	-	-	-
Singapore	227	204	285	266	243
Thailand	2,753	3,929	3,884	4,087	4,220
Total	**19,978**	**18,564**	**18,868**	**18,922**	**19,676**

Markets

Asian seabass has a regional market, which is almost exclusively limited to the Southeast Asian and Far Eastern countries. However, it has high potential for gaining a larger market, as it has the appearance of a normal white fish and is similar to fish species sold in the USA and Europe. It is envisaged to become a commodity fresh/chilled product as it probably is the first species to be produced at low costs.

Snappers are sold in the world market but often in processed, filleted form. In the short term, snappers (which already hold an interesting live fish segment) are predicted to dominate this segment even at larger volumes. Due to their worldwide presence in the capture fisheries and strong demand for snappers in filleted form in Hong Kong, China, Japan and USA markets, they will also enter these areas as a high quality product in the fresh/chilled segment.

Conclusion of Market Development

The potential of several species in the future Asian marine fish farming in different market segments is described below:

- Seabass
  live (small to medium volume)
  fresh or chilled (large volume)
  fillets (very small volume)
- Snappers
  live (medium volume)
  fresh or chilled (large volume)
  fillets (small volume)
- Groupers
  live (small volume)

Others:

- Pomfrets
  fresh or chilled (medium volume)
- Black kingfish/cobia
  fresh or chilled (also for sashimi) (medium volume)

fillets or steaks (medium volume)

- Yellowfin tuna
  fresh chilled for sashimi

This scenario is based on the product qualities, the traditions, and volumes in present markets as well as on the opportunities for developing more efficient farming procedures of the specific fish species.

Black kingfish shows large potential to be a major aquaculture species. It has a very diverse market and it possess very good qualities for aquaculture. It has a small market volume at about USD 10/kg. In Chinese Taipei, it is reported to grow to 4 kg to 5 kg in twelve months and up to 8 kg to 10 kg in sixteen months.

The yellowfin/bigeye tuna could be developed as the major farmed species in the tropics. It already holds a large market share, for example in Japan (importing 71,000 mt fresh/chilled and 300,000 mt frozen). The stocking source should come from the existing purse seined undersized (1 kg to 5 kg) tuna caught live together with skipjack for canning. Sarawak/Sabah region has sufficient stock to produce more than 30,000 mt if 25% of the source is being used. The selling price for grade A sashimi tuna is USD 10/kg (average price USD 7/kg).

Scenario for Appropriate Technologies and Development Approach in Asia

The scenario will describe the developed marine fish farming sector. The development approach will differ in the regions and countries according to the socio-economic conditions, which cannot be simplified or generalized. Therefore, it may vary by country and region whether it will be achieved in medium or long term.

The fully developed scenario:

The farming process will take place in more exposed areas. It will adapt European technology using either 60 m to 100 m circumference floating plastic (PEH) tube cages or hinged steel cages of large volumes with 10 to 20 deep nets. (in Norway both types are used in a 50/50 ratio – the most important is that they have large volumes – this is now also the trend in the Mediterranean seabass and sea bream production). The mooring system has to be specially designed to cope with the wave and tidal conditions of the more exposed areas. The offshore cages will make it possible to leave protected areas and use much larger areas for farming. It will be possible to provide fish with a better environment due to better flushing, more stable abiotic conditions and possibility to escape from wave impact using deeper nets – altogether producing more healthy fish.

More advanced technology also means better management, implementation of feeding strategies, disease prevention (including vaccination, localization strategies, efficient quarantine or restrictions in movement of cultured fish between zones), and applying a regulatory framework not only to protect the environment but also to protect the investment of the farmers.

Other key figures are as follows:

- Stocking and harvesting densities are about 5 to 20kg/m^3 depending on the size of fish (small fish – low densities), and the flushing (available oxygen in water). Presently there is a misunderstanding by many farmers and researchers that good management means the quantity of fish (biomass) produced per m^2 or m^3. They forget that this sort of increased efficiency does not reduce the production costs but increases risk of disease. The risk of disease would be higher as high densities stress the fish. The savings on the overall operational cost side by using very high densities is low since the depreciation of the investment in cages typically constitutes only with a few percentage points of the operation cost.

- "Normal" mortality is down to a few percent. At present, an average mortality between 30% (snapper) and 80% (seabass) is considered normal (for example, in Malaysia). Apart from nearly doubling the price of fry used to produce one fish, it also means loosing money on feed spent on fish that die (the amount of money depends on when during the production cycle the fish dies).
- By using inert pelleted feed, the feed conversion rate (FCR, i.e. kg feed to produce 1 kg fish) is brought down to 1.5 to 1.8. This makes it possible to apply better distribution and logistics, and handle larger production. When a mixture of trash fish and feed additives is used, the average FCR is 6 to 7, which apart from logistical problems also creates a larger environmental impact and makes it difficult to apply optimal feeding regimes (the trash fish sources and quality are unstable).

The investments in modern technology typically are thought to be high. With the risk of simplification, a comparison has been made between the present farm investments in Malaysia (for bass and snapper) and Norway (salmon).

DOFM estimates that the capital costs for a Malaysian marine fish cage farm is from RM ½ to 1 million. (US$ 1 = RM3.8). Production is from 10 to 30/y. During auditing, a Ketam Island farmer estimated his investment to be about RM 2 million for a farm (including a boat) with the capacity to produce 100 t of sea bass and snapper a year. This farm employed ten people giving an average production per worker of 10 t fish/y.

In Norway the official total investment figure for a salmon farm concession covering a production of 300t/y is RM 1.5 million i.e. 0.5 million for 100 t capacity. A company starting on a new concession in 1999 invested RM 3.4 million for a 1,000 t production capacity. It should be noted that most Norwegian farm companies hold many concessions and each farm worker will produce an average of 500 t of salmon a year (up to 700 t).

Table 2. Comparison between Malaysian and Norwegian fish farm set-up

	Investment per 100t prod.	**Productivity per worker**
Malaysia	RM 2 million	10 t marine fish/year
Norway	Less than RM 0.5 million	500 t salmon/year

Table 2 indicates that willingness to invest sufficient amounts is present in Malaysia. The Malaysian hardwood raft cages last for five years, the offshore cages last for more than seven years, which also indicates that it is not directly a matter of higher costs for modern technology. Probably one issue is lack of demonstration of the adaptability of this type of cage farming.

When numbers in Table 2 are reviewed, precautions should be taken in expecting the same investment and efficiency figures in present Asian marine fish farming because these are two different types of fish production approaches (Table 3).

Table 3. Differences in marine fish farm production set-up between Asia and Norway

Asia	Norway
• Multi-species farming • Use of trash fish as main feed • Use of small volume cages • Partial harvesting • Harvesting sizes 600 g to 1000 g • Live fish sales	• Farming of one species • Use of inert/pelleted feed • Use of large volume cages • All in/all out productions • Harvesting sizes 2,500 g to 6,000 g • Fresh/chilled etc.

These are obvious reasons for the higher productivity achieved in Norway. There is much more handling involved when producing fish for the size up to 1 kg only and partially harvesting.

It should be noted that the low productivity per farm worker is not a local Malaysian problem. In Chinese Taipei the traditional marine fish farm accomplishes a productivity of 5 to 10t/y/farm worker. It should be possible to achieve a productivity of 80 to 100t/y/ per farm-worker if adapting more efficient approaches to the Asian production, especially the use of pelleted feed and larger cages and all-in all-out practices.

A precondition is the domestic fry production, which can be achieved through a focused applied research on methodologies rather than species. A country cannot depend on import of large quantity of fry from Thailand and Chinese Taipei. It will be impossible to apply the appropriate disease prevention measures if imports to provide the majority of the fry stock (even when establishing quarantine facilities).

Value Added of Present Farming and the New Value Added in Efficient Farming

The present marine farming value added figures are presented in Table 4.

Table 4. Value added calculations of sea bass from cage farming in Malaysia 1998

Item	Price/kg VA (RM)	%
Retail	15.36	
Wholesale	12.80	
Sales value ex-farm	8.26	
Cash (production) cost	6.88	
Value added at retailer	2.56	20
Value added at wholesaler	4.54	55
Value added at fish farmer	1.38	20

Reduced production costs will allow entry to segments other than the live fish market. This will break the control of a few wholesale dealers, and open markets for selling large volumes (in competition with capture fisheries) of quality fresh/chilled fish.

Table 5 shows the projected value added in Malaysian marine fish farming by year 2010. It has been computed from Table 4 by predicting a conservative decrease in production costs of 20% over ten years by implementing more efficient approaches. In Norway, ten years of development reduced the production cost of salmon by 45%. The exporter price margin is not forecast to change dramatically (Norway experience). For example, the exporter price margin is 82%, while this is 58% in Norway. This should leave enough room for performing large generic marketing in for example Malaysia.

Table 5. Projected value added of seabass from cage farming in Malaysia in 2010

Item	Price/kg VA (RM)	%
Wholesale/export price	10	
Sales value ex-farm	6.6	
Cash (production) cost	5.5	
Value added at wholesaler/exporter	3.4	52
Value added at fish farmer	1.1	20

Approach

What are the development directions? Company or family farmer approach. In Malaysia, the Government and the Economic Planning Unit (EPU) have tried to encourage large companies to take responsibility for development of marine fish farming (so that they can copy what has been achieved with the oil palm plantation industry) and thus leapfrog development. This is not likely to be a sustainable development for the country. The companies would develop fish farming based on imported technology and management. If the development is not based on a broad domestic base building on tradition, human capacity and resources at all levels, the approach will only lead to some success stories but will not have the overall impact on the country. The competencies will stay as the company property and will be disseminated slowly to others even the government offices. The development has to take place by assisting progressive fish farmers and by developing a national R&D competence within the national institutes. Large companies may become interested when they see that they can gain a competitive edge for example through their logistics.

Case Study of a Step by Step Approach for Developing Appropriate Technologies

To avoid the impression that this paper is a promotion of high efficiency farming technology, only the last discussion will deal with increasing efficiency. However, it will provide step by step solutions according to the capability of the target group.

It has to be remembered that the overall development objective is not to develop the farming into an efficient industry driven only by the possibilities (the technologies). The approach has to be focusing on the present socio-economic situation and needs of the country or region (improvement of the livelihood).

This paper will present this approach taking as an example the poor land-less fisher families in northern and northern central Vietnam, thousand of whom are forced to leave the inshore fisheries due to stock depletion. It is about developing improved practical technologies, which will increase their opportunities to improve their livelihood.

The project is a part of the capacity building project. It is financed by the Vietnamese government and Norwegian development agency (NORAD) and is carried out by RIA-1, Vietnam with participation of a.o. SINTEF F&A, Norway

With regards to broodstock keeping, this creates obvious constraints to other pilot marine fish hatchery activities in Vietnam. To eliminate this immediate constraint within the project period and to concentrate on capacity building within the hatching technology, a shortcut had to be made. Two very small-sized plastic-tube cages were imported to provide an immediate safe housing of the valuable broodstock in the harsh exposed conditions of the Cua Lo area.

Apart from the above mentioned cages, a locally built wooden raft structure with a central platform with a hut and smaller surrounding cages has been installed for handling of stock during biological tests. The traditional rigid raft design has been given approved hydro-elastic capacity by the simple addition of car tyres as hinges between the cage compartments to make it sustain more exposed conditions of the site than normal marine farming conditions in Vietnam.

Low-cost Cages

It is understandable that this cage technology is not appropriate for the future marine farming development in Vietnam even for the medium term. These cages are suitable for research work at the institute, but the coast of central and northern-central Vietnam is very exposed and the target fisher society is very poor. The plastic-tube cage – even if produced in Vietnam – is too expensive and the present local rigid raft-cage technology can only be applied in very protected localities, thus often causing adverse environmental impact on the very restricted resources.

A draft design of a new promising cage structure has been made. This cage will be cheap, made from locally available material, and will withstand typhoons in very exposed localities. It will also take into consideration the locally used fishing boats.

The new cage will consist of small floats, rope and net. The mooring lines keep the net volume distended; rendering a heavy and expensive frame superfluous. This cage structure is also thought to be suited for operating from the smaller circular woven bamboo dinghies found by the thousands along the coast. The unique issue in the draft concept is the special mooring at the bottom of the net, which will make the net cage automatically submerge during strong winds and currents. This will prevent the strong deformation normally seen in traditional concepts, when they are exposed to storm and thus makes the concept promising for the typhoon belt of Vietnam. Pilot tests of the cage will have to be performed during the coming typhoon season. The handling procedures will also be tested.

As mentioned earlier, it is mandatory for production efficiency and the well being of the fish that larger volume units are used in future. One large cage is better than ten small ones. When entering more exposed areas, this issue becomes more important because fish need the possibility to “escape” down in the net pen, when waves become too severe.

Very preliminary investment cost calculations have been made based on local market prices (not negotiated and not volume purchases) of a 30 m-circumference cage unit, which costs less than US$ 1,000 all included. In comparison with the price of imported plastic cages (less the net), the cost of the new structure is less than 3% of the cost of foreign cages and may be 10% of the floating structure of present local cages with similar surface area.

Low-cost Feed

The second topic given special attention is feed. Presently, trash fish are used as feed in marine fish farming in Vietnam. The use of trash fish poses several immediate constraints to farming. The supply and quality are fluctuating due to seasonality or due to weather conditions preventing small boats and dinghies from fishing. To balance this, farmers either let the farmed fish starve (when feed is in low supply), or invest in freezers, which can act as storage. Both of these solutions are less than optimal, the first one for obvious reasons, the second - the use of freezers - is not suitable on a wide scale. Many of the fisher families will not be able to invest in freezers, will not be able to pay, or can not rely on a continuous supply of power.

An alternative or supplementary feed storage strategy is to produce fish silage by adding acid to the trash fish. The silage can be produced, when trash fish is plentiful and then be stored for longer periods. When the silage is used, it is gelled by adding a colloid from local seaweed production to produce soft pellets as an “on-farm production” process. The use of the soft pellets would initially be a supplement when fresh trash fish are not available. After an introduction period, farmers may find additional benefits from the use of soft pellets (for example, diseases and parasites carried by the food fish will be eliminated).

The technology will not demand large investments and (to an outside observer) it looks very similar to the present traditional fish sauce production. The project has a strong focus on development of a simple practical low-cost technology and should be seen as a first step in making the farming operation more feasible. It also includes better feeding strategies.

Conclusions

Most of the present marine fish farming is farming of high-value species like groupers. This is an economically feasible production. Within the present farming structure and technological level, it is questionable if many other alternative species exist (unless appropriate and more efficient technologies are developed). The focus on grouper is fully understandable within the present context of inefficient farming procedures and insufficient fry supply. However, the present farming technology is keeping farmers trapped in grouper production which, apart from their high-value, shows weaknesses and threats for farming in the future.

- Grouper fry are taken from the wild and are one of the most difficult species to mass produce in hatcheries
- Grouper species are typically solitary, even sedentary species, which do not make full use of the production volume in cages, as the fish aggregate along the walls or floor of the net
- Groupers are marketed exclusively for the “live fish” market segment. The selling price (though relatively high) does not bring the “normal” price margin (or value added) to the farmer as middlemen and foreign traders easily control the trading and it is a very focused market (Hong Kong, China). From a development perspective, this means that the main value added is directed abroad. Another issue with the grouper “live fish” segment is that the Hong Kong, China market (the target of grouper production for most countries in the region) holds only a limited volume of about 5,000 mt. It is predicted that the market will show a supply/demand collapse when the large R&D effort put into grouper culture by countries in the region becomes fruitful and production increases as was the case with salmon and Mediterranean seabass and giltheaded sea bream. This would leave the marine fish farmers in a very vulnerable situation if they have only the present technology and farming management as a capacity base for their production

It is necessary for fish farmers to diversify or escape from the “grouper trap” by producing other fish species with larger market volumes within the “live fish” segment and fresh or chilled market segment. At the present stage, the latter segment could seem too inaccessible for poor farmers, but this is not true as it can be seen from the trading of products from freshwater fish farming. The issue is putting more effort into research and development of appropriate technologies rather than focusing only on biology.

Recommendation

We should be able to design a low-cost practical production technology by using high technology base to design appropriate solutions. The recommendation is to develop a collaborative programme for developing appropriate marine fish farming technology in the region adapted to the needs of farmers or people in need of finding a better livelihood through marine aquaculture.

Towards Sustainable Harvesting of Live Reef Food Fish Species in the Solomon Islands

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Abstract

This paper provides the information on the Live Reef Food Fish Trade (LRFT) in Solomon Islands and some of the grouper species that are collected. It described some of the key concerns on LRFT, and some of the management strategies for sustainable coral reef fisheries in the Solomon Islands.

Introduction

The Solomon Islands lie in the south-west Pacific, to the east and south of Papua New Guinea. The country consists of two roughly parallel island chains with six major island groups - Choiseul, Isabel, and Malaita are in the northern group and New Georgia, Guadalcanal, and Makira in the south. There are 992 islands that collectively have a land area of nearly 30,000 km^2 distributed over 1,280,000 km^2 of sea. The Solomon Islands are the second largest archipelago in the South Pacific.

About 80% to 85% of the land and marine resources in the Solomon Islands is customarily owned by family groups or clans. The land and marine tenure system dictates that family groups or clans legally have strong rights to ownership of and decision making for their forest and near-shore marine resources. Their livelihood is dependent on the continuation of these resources.

The reliance of Solomon Islanders on marine resources is reflected in one of the highest per capita seafood consumption rates in the world. A survey conducted by the Japan International Cooperation Agency (JICA) on the Development Study on the Improvement of Nationwide Fish Marketing System in Solomon Islands estimated per capita consumption of fish in Honiara was 47.9 kg in 1992. A family of 6.5 persons consumes 2.5 kg of fish per meal, four times a week. Shellfish consumption appeared to be concentrated in the Western Provinces (Skewes, 1990).

Inshore marine resources play a significant role in the lives of Solomon Islanders and can be critical to the economies of the nation. However, few management controls are in place to ensure that harvest remains at sustainable levels.

The fisheries sector accounted for an estimated 6.7% of GDP in 1993 and had increased to about 12% in 1998. The domestic tuna industry is the largest employer in the Islands. Fish was the country's major export in 1998 but fell behind log export in 1999. Marine products exports, including tuna, accounted for SBD $159 million in 1999.

Coastal resources exports peaked at SBD $16.6 million (1992) but fell to SBD $l0.6 million (1999) with finfish being the most important coastal marine resource. The annual production from subsistence and artisanal fisheries of 11,150 mt has been estimated to have a nominal value of more than SBD $60 million.

Solomon Islands and the Live Reef Food Fish Trade

In 1996, according to industry representatives, "stocks in the Philippines and Indonesia are expected to collapse within a few years, after which the trade will focus increasingly on Papua New Guinea and the Pacific Islands". The LRFFT harvesting operations since then have moved to the "new" world.

Foreign interest in the LRFT began in the Solomon Islands in 1994 and a licence was subsequently granted without much thought to Ika Holdings, a Hong Kong backed company. Concern about the LRFFT arose in November 1997 when another foreign investor began "surveying" Isabel Province for possible fishing grounds. Complaints came from the Arnavon Marine Conservation Area Management Committee to The Nature Conservancy. In response, TNC funded Dr Bob Johannes to visit Honiara during the Provincial Fisheries Officers meeting to brief the National and Provincial Fisheries Officers on the LRF trade and its implications. Dr Johannes also briefed the Minister on this issue, which later resulted in the Minister imposing a moratorium on all new licenses in February 1999.

In December 1997, the Principal Fisheries Officer (Research & Resource Management), attended an APEC Workshop in Hong Kong on Destructive Fishing Methods in the LRFT industry and invited international assistance to provide support to the little known LRFFT in her country. Upon her return, a preliminary survey of the LRFT was undertaken in the Solomon Islands. A number of problems were identified. These include fishing during spawning aggregations, under-valuation of and/or under-payment for fish, biased weighing and under-reporting of fish exported. It was also discovered that, although actual fishing started in 1995, the Fisheries Division had no records of any exports until 1997 when about 4,000 kg were reported on export forms. Moreover, large post-harvest losses have been reported at the point of collection and in the holding tanks, as well as during the transportation of the fish to the markets in Hong Kong. This prompted the immediate need to develop a strategy for the management of LRFT in the Solomon Islands. The Minister for Fisheries considers improved management of the LRFT a very high priority and is committed to implementing appropriate management strategies.

It is clear that the status of the fishery in the Solomon Islands is poorly understood. The existing fishery activities are not regularly monitored, primarily because of lack of resources in the Fisheries Division. Furthermore, it is likely that the foreign investors involved in the trade will target new areas in other parts of the country. Consequently, the fishery needs to be better understood to allow development of the appropriate policy and management responses sought by the Minister.

In Western Province, the LRF fishery started out in Vella La Vella Lagoon in 1994, and was pursued year round by a company called Ika Holdings. Insufficient fish were obtained according to the company. Pulse fishing, targeting seasonal grouper spawning aggregations, began first in Marovo Lagoon, then in Roviana Lagoon and Ontong Java.

The primary targets of the spawning aggregation-based fishery were three species of grouper, the flowery grouper, *Epinephelus fuscoguttatus*[4], the coral trout, *Plectropomus areolatus.* and the camouflage grouper, *E. polyphekadion*. All three aggregate to spawn at the same locations and during the same seasons and moon phases.

The other target species include *Cheilinus undulatus* (humphead/Maori wrasse) and *Cromileptus altivelis* (highfin grouper). This increasing demand for live reef fish has encouraged the use of destructive fishing methods. Some of the effects can include the following:

- loss of target species
- a substantial by-catch which is often wasted
- increasing resource and reef ownership and control disputes within communities, and
- elimination of large spawning aggregations of groupers that have sustained coastal villagers for centuries through intensive targeting by hook-and-line fishing for the live reef fish food trade

The only places with effective control over activities on the fishing grounds are those where customary marine tenure or some other form of local control over the fishing grounds exists. Exclusionary rights are the key to management success. However, even with these controls, the value of the trade and some of the operating strategies used, have resulted in ownership and control disputes within communities. These disputes have often continued well after the LRFT operators have moved to new areas.

While most of the information on this fishery tends to be negative, based on experiences of the uncontrolled or ineffectively managed fisheries, there is the potential for "adding value" to the Pacific region's reef fish resources. This is if the resource is sustainably exploited and products are exported in good condition to the respective markets. However, for these fisheries to be sustainably developed, and environmental impacts minimized, careful and specific management and strict enforcement will be required to alleviate any potential negative impacts.

The Solomon Islands has initiated a management strategy aimed at better management of the fisheries resources owned by villagers. The economic impact of new management regimes will need to be taken into account in this research. The villagers presently have few, if any, other cash-earning opportunities. Presently, some villages earn several thousand dollars during a three to four month fishing season, an income stream that they are unwilling to give up completely. Consequently, economic sustainability, going hand-in-hand with biological sustainability, is important in the proposed research activities. The spillover benefits from this work are likely to be substantial as the fishery expands in Solomon Islands and other areas in the Pacific, including Fiji where there are similar concerns about the LRFT.

There is considerable interest amongst foreign investors in expanding the LRFT in the Solomon Islands. However, due to the potentially destructive nature of the industry, the Fisheries Division has placed a moratorium on increasing the number of companies until an appropriate management strategy is in place. For these reasons, the government accords the LRFT Project the highest priority and fully supports the

[4] Sometimes misleadingly referred to as the "giant grouper" in the Solomon Islands. Elsewhere the term giant grouper is reserved for *Epinephelus lanceolatus*, which is called "rava" in the New Georgia area.

activities leading to a sound management plan that will result in the sustainable use and development of reef fish stocks.

Consequently, the Fisheries Division made a direct request to the Australian Centre for International Agricultural Research (ACIAR), which resulted in a major research project being funded. The request was about developing a research project into the social and economic aspects of the LRFT in the nation. As there is regional interest and concern for the LRFT, requests to technical groups such as the International Marinelife Alliance - Philippines (IMA) were also forwarded to those organisations. The Nature Conservancy (TNC) has also offered technical assistance for development of a management strategy. This work forms one component of the regional strategy - developed with SPC, IMA and the World Resources Institute - to address the trade in the Pacific islands region.

Key Concerns

As discussed before, inshore marine resources play a significant role in the lives of Solomon Islanders and can be critical to the economies of the nation. However, few management controls are in place to ensure that harvests remain at sustainable levels.

Given an annual growth rate of 3.5%, which is among the highest in the world, the government is concerned with exploitation of the finite marine resources. As the population grows and the commercialization of fisheries resources increases, the production to satisfy growing demand will encourage the widespread use of efficient and often destructive fishing methods. Coupled with weak institutional arrangements and low awareness of the biology of targeted species and sustainable resource use, resource owners are often lured by quick cash and fail to contact the proper authorities for advice.

Fisheries resources are potentially renewable if exploited sustainably. However, they are currently under threat due to over-efficient and destructive harvesting. In addition to the damage caused by destructive fishing, the Solomon Islands reefs and fishing grounds are subject to a variety of other assaults resulting from land-based human activities. Widespread ecological degradation is a growing concern. Determining current levels of use is far from easy due to lack of information about the volume of domestic and international trade. LRFT targeting spawning aggregation has continued for more than five years without any form of management or control.

There is also lack of technical skills associated with the trade. These skills include best handling methods, cage capacity, location and transportation and have to be taught. Post harvest losses have been reported to be as high as 90%. As the company probably built this loss into their operation, this resulted in lower returns to resource owners. Since the trade started, resource owners have been paid a flat rate of US$ 0.50/kg of live reef fish. This has slowly increased to US$ 1/kg.

Another important concern is the lack of transparent and accountable systems of negotiations between the company and resource owners. This has invariably caused a number of disputes among resource owners. The lack of a defined system of obtaining permission and licenses has also caused problems at the provincial and national level.

Current Situation

An interim moratorium has been in force on the export of live food fish since 6 February 1999 and will be in place until the live reef fish management plan is available (November 2001). An interim management plan prepared in July 1999 and submitted to the Fisheries Advisory Council was not accepted because “it lacked teeth”. The FAC recommended that a set of regulations be drafted for the Live Reef Fish Trade before it will reconsider lifting the current moratorium.

Unfortunately, during this moratorium the Western Provincial Government issued a business license to the South Pacific Live Fish and Marine Export company. The company bought fish from fishers during spawning aggregations in Roviana and Marovo Lagoons. On 18 December 1999, the company fish collecting vessel sank just outside Mongo Passage, Marovo Lagoon. The vessel, Western Star (formerly called John Franklin), was transporting almost two mt of live fish from Roviana Lagoon to the holding pens at Vakambo, Marovo Lagoon. This loss has forced the company to stop buying fish.

Management Strategy

The management strategy will only be effective if there is political will to implement and enforce management actions, cooperation of the industry and reef owners, and adequate support (financial, legal). If this support and cooperation are not possible, then the moratorium on the fishery should remain in place.

The proposed management actions are of interim nature, until such time as the necessary economic, social and environmental information is collected and analyzed to finalize the management strategy. A precautionary approach to the management of the fishery has been adopted, which may appear onerous to the industry, but is fully justified based on the record of the industry in the Asia-Pacific region - in particular the potential for extremely negative environmental and social impacts. However, with the recent scale of the fishery it is expected that the costs associated with effectively managing and controlling the fishery will be high and time consuming.

With the exception of the Great Barrier Reef in Australia, the only places with effective control over live reef fish operations are areas where customary marine tenure or some other form of local control over the fishing grounds exists. Security of tenure provides an essential incentive for conservation of the fishing grounds. The Solomon Islands has fishery laws that recognize customary tenure. Permission must be obtained from both the customary reef owners and the relevant provincial government.

The preliminary draft objectives of the interim management plan are as follows:

- To ensure that maximum benefits accrue to the village-based fishers
- To manage live reef fish operations to ensure their economic and environmental sustainability and the long-term conservation of the fishery resource, and
- To ensure the application of the fisheries conservation and management principles of the Fisheries Act 1998 (Part II, §8), in particular the application of the precautionary approach to the conservation, management and exploitation of fisheries resources

The proposed strategy is a form of limited entry/access fishery. It involves issuing limited annual conditional licenses (for local and foreign vessels) for purchasing of live reef fish in specified areas only. Only village-based fishers, with the agreement of the respective customary reef owners, shall be allowed to fish. Enforcement will be conducted through the following means:

- checking of product exports by the authorities
- regular data submission and reporting to the Fisheries Division
- spot checks by fisheries officers (provincial and national) on the operations (at all stages), and
- access agreements with customary reef owners (enforced by the customary owners (but with appropriate checks and balances) and provincial fisheries officers)

The export of live reef fish will only be permitted from designated ports.

Proposed Management Actions

The Minister and Director of Fisheries have recognized the live reef fish trade as a fishery requiring special consideration and needing the development of a specific management plan. This is supported by the Fisheries Act 1998.

The following management recommendations adhere to the Fisheries Act 1998 management and development objective:

> "The objective of fisheries management and development in Solomon Islands shall be to ensure the long-term conservation and the sustainable utilization of the fishery resources of Solomon Islands for the benefit of the people of Solomon Islands."

The proposed management actions take into account the specified fisheries conservation and management principles, especially the application of the precautionary approach to the conservation, management and exploitation of fisheries resources in order to protect the fisheries resources and preserve the marine environment. The national live reef fish management plan will establish the overall management framework. Each province that intends to participate in the live reef fish trade must prepare its own live reef fish management plan. These plans will be equal to or stricter than the national management plan.

Summary

Given a history of destructive fishing methods, the Solomon Islands government bases its management actions on fisheries conservation and management principles as defined in the Fisheries Act. With the application of the precautionary approach to the conservation, management and exploitation of fisheries resources, the government hopes to protect vulnerable fisheries resources and preserve the marine environment.

At the same time, it hopes to maximise sustainable benefits to Solomon Islanders from their resources through a more proactive resource management. Solomon Islands' vision for the management of its reef fisheries will operate on a set of clear policy guidelines.

The National Live Reef Fish Management Plan will establish the overall management framework. Each province that intends to be involved with the live reef fish trade must prepare its own live reef fish management plan. This will ensure fair returns to the resource owners and encourage genuine reputable investors by setting clear roles for government facilitators and private sector developers.

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Preliminary Report on the Regional Survey of Fry and Fingerling Supply and Current Practices for Grouper Mariculture

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Abstract

This paper provides initial research outcomes of an APEC funded project on regional survey of fry and fingerling supply and current practices for grouper mariculture in Southeast Asia. The purpose of the project was to evaluate the biological sustainability of the grouper fry fishery in Southeast Asia. The survey was carried out from June 1999 to August 2000.

Data Collection

Economies:

- China
- Vietnam
- Thailand
- Malaysia
- Indonesia
- Philippines
- Chinese Taipei
- Hong Kong, China

Questionnaires designed specifically for:

- Packers
- Fry fishers
- Fry traders
- Fry exporters
- Mariculturists

Interviews and correspondence with:

- NGOs
- Literature review
- Private businesses
- Government personnel
- Research establishments
- Inter-governmental organizations

Species And Sizes

Sizes – settlement to 150 mm TL

Naming problems and misidentifications:

Epinephelus akaara	*E. bleekeri*
E. awoara	*E. lanceolatus*
E. coioides (= E. suillus)	*E. fuscoguttatus*
E. amblycephalus	*E. sexfasciatus*
E. trimaculatus (=E. fario)	*E. malabaricus (= E. salmoides)*
E. tauvina?? (largely misidenifications)	*Cromileptes altivelis*
Plectropomus leopardus	*P. maculatus*

Capture Methods

Passive:

- traps
- bag and fyke nets, and
- artificial shelters and reefs

Active:

- pushnets
- hook and line, and
- scoop and dip nets

Trade, Monitoring And Regulation

- Regional and local trade
- Regulations (capture/export)
- Monitoring (capture/trade)

Biological Considerations

Capture methods:

- by-catch
- impacts on habitat, and
- mortality of target species

Timing of capture/settlement

Long-term trends in capture:

- size of fish
- numbers of fish

Adult/juvenile fishery interactions

Preliminary conclusions

- Need for reduction of destructive fishing and by-catch
- Need for monitoring regulation of catches and exports
  (recommended for all economies to adopt a similar Harmonized Coding of Commodities, possibly following Hong Kong, China's lead)
- Determine interaction between adult and juvenile fisheries
  (fishery of juveniles for mariculture affects capture fishery for adults; the two sectors are closely linked)

- Recommend there be no export of fry or fingerlings. Source economies benefit more by value-adding (through grow-out) in-country; non-export fishing practices are less wasteful and no exports should reduce disease spread
- The juvenile fishery is not sustainable in some areas
- APEC economies should adopt the FAO Code for Responsible Fisheries (also recommended by the 1997 APEC Destructive Fishing Workshop in Hong Kong).

An Overview of the Komodo Fish Culture Project

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Abstract

This presentation provides an overview of the Komodo Fish Culture Project carried out by the Nature Conservancy Indonesia Coastal and Marine Program together with the Indonesian Park authority in Komodo National Park for extensive marine conservation purposes. This program involves local communities and was identified as a way to steer fishers away from destructive and unsustainable fishing methods.

Background

Komodo National Park is located between Sumbawa and Flores in the Nusa Tenggara Timur province of Indonesia. It is famous as the last remaining habitat of the Komodo dragon. The Park is one of the most diverse and richest marine environments in the world, featuring coral reefs, rocky shores, sea grass beds, sandy bays and mangroves.

There are presently some 3,500 inhabitants living within the Park, spread out over four settlements. An estimated 17,000 people live in fishing villages directly surrounding the Park. Park inhabitants mainly derive their income from a pelagic lift net fishery targeting squid and small pelagic fish, a method that is not threatening the coral reef resources of the Park. Several surrounding communities, however, are involved in fishing with cyanide and hook-and-line to catch valuable fish species (groupers and Napoleon wrasse) to supply foreign markets with live food fish (mainly Hong Kong, China). The extremely high exploitation pressure on the grouper stocks, and the poisoning of the coral reefs through the use of cyanide severely threaten the marine biodiversity in and around Komodo National Park.

To abate these threats, The Nature Conservancy Indonesia Coastal and Marine Program together with the Indonesian Park authority implemented an extensive marine conservation program for Komodo National Park. Development of a fish culture enterprise that involves local communities was identified as a way to steer fishers away from destructive and unsustainable fishing methods. The development of a fish culture enterprise would serve as a model for other rural areas in Indonesia, thereby contributing to the market transformation of the live reef fish trade from unsustainable, capture-based to sustainable, culture-based. Fish culture consultants who visited the Komodo area in 1997 reported that the Komodo area is very suitable for the deployment of fish cages: water quality is excellent, there is little rainfall, and there are many locations that are sheltered from storms and waves. A marketing channel for wild-caught live food fish was already in place, and local communities had experience with keeping wild-caught fish in cages. Therefore, it should be relatively easy to involve local communities in the grow-out phase. However, one of the main constraints was the availability of grouper fingerlings, the ‘seed’ for the culture enterprise.

Cultured Species

Starting in 1997, a method to obtain fingerlings from the wild was tested in the Komodo area with the assistance of Philippine consultants. This method, gango, has already been used extensively in the Philippines. After one year of field trials in the Komodo area, it was concluded that gango puts additional pressure on the wild stocks, both those of groupers and those of non-target fish. Therefore, it was decided not to implement gango but to concentrate on full-cycle fish culture. In full-cycle fish culture, broodstock are kept for the production of fingerlings, and thus the impact on the wild stocks is minimal. The fish that were collected during the gango trial were used to start building broodstock of four species of groupers (estuary grouper, *Epinephelus coioides*, malabar grouper *E. malabaricus*, and the high-prized mouse grouper *Cromileptes altivelis*), of the commonly cultured barramundi *Lates calcarifer* and mangrove snapper *Lutjanus argentimaculatus*. On recommendation of experts from Indonesia and Australia, the Malabar groupers were later replaced with tiger groupers *E. fuscoguttatus*, because the latter are easier to culture. The fish that were collected during the gango trial were supplemented with wild-caught fish from local fishermen. Presently, 200 groupers, each weighing between 2 kg and 30 kg, and 130 mangrove snappers and barramundi are kept as broodstock for the planned hatchery.

Collaborating Institutes

As culturing of grouper still poses some technical challenges, the fish culture project created partnerships with institutes that can provide the necessary know-how. A Memorandum of Understanding was signed between the Indonesian Central Fisheries Research Institute (CRIFI) to secure the cooperation of one of its institutes, the Gondol Research Station for Coastal Fisheries. As one of the first fishery research institutes in the world, Gondol succeeded in reproducing mouse grouper fingerlings from captive broodstock. In addition, a close partnership was established with the Queensland Department of Primary Industries because of their extensive expertise in fish culture, particularly in culture of barramundi. The project also joined the Network of Aquaculture Centres in Asia (NACA) to link up with aquaculture experts in Southeast Asia.

In July 1999, an expert team visited the Komodo area to collect data for preparation of a business plan for a fish culture enterprise. The team consisted of Mr Bill Rutledge (a US consultant), Dr Mike Rimmer (Queensland Department of Primary Industries, Australia) and Dr Ketut Sugama (Gondol Research Institute for Mariculture). The business plan suggests that seabass and estuary grouper be used to gain experience with hatchery techniques during the start-up phase of the project, after which the focus will be changed to mouse grouper. Mouse grouper is more profitable, but its culture also poses more technical challenges. The business plan concludes that to start up a hatchery-based grow-out enterprise in two years, with a capacity of 27 mt/year, capital requirements amount to US$ 280,000. Operational costs in the first three years would amount to US$ 460,000, and the enterprise would break even after five years. After the facility is fully operational, annual profits would amount to US$ 435,000. Dr Stephen Battaglene, Senior Research Fellow of the Tasmanian Aquaculture and Fisheries Institute reviewed the business plan.

A portion of the funds to start up the hatchery project has been secured and a suitable location has been identified. It is expected that the construction of the hatchery will start in July 2000.

Seafarming and Community Development in the Philippines

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Abstract

This paper provides information on the seafarming activities in the Philippines, which includes milkfish, seabass and grouper cage and pen culture. It also provides some other seafarming alternatives including mud crab, seaweed, mussels and oysters. The paper gives information on community-based coastal resource management as a strategy for community development. The Philippines Government Fishery Resources Management project was outlined. The problems and issues associated with seafarming in the Philippines are described.

Introduction

The Philippines is an island nation with a total territorial water area of 222 million hectares including the exclusive economic zone (EEZ). Coastal waters comprise 12% or 26.6 million hectares; the rest are oceanic waters. The Philippines has one of the longest coastlines in the world - 17,460 km. Swamplands total 338,400 hectares, of which 232,065 hectares are brackish water and the rest are freshwater. The existing fishponds have a total area of 253,854 hectares. Other inland resources are lakes (200,000 ha), rivers (31,000 ha), and reservoirs (19,000 ha).

In 1998, the Bureau of Fisheries and Aquatic Resources (BFAR) reported that the contribution of fisheries to the total gross domestic product was 3.9%. Fisheries have contributed 20.1% to the agricultural sector in terms of the gross value added. The fishery sector employed close to one million people in 1998; 675,677 were small-scale self-employed fishers in the municipal fisheries; 258,480 were employed in aquaculture and 56,715 worked in commercial fisheries.

The total fish production in 1998 was 2.79 million mt valued at P84.6 billion. Aquaculture contributed 34.4% in volume (959,000 mt) and 30.6% in value (P25.9 billion). Municipal fisheries produced 891,000 mt (31.9%) valued at P29 billion (34.3%). Commercial fisheries produced 941,000 mt (33.7%) valued at P35.1 billion (35.1%). In international trade, 1998 fishery exports (185,758 mt) exceeded imports (165,989 mt). The value of the net export was US$ 446.7 million. In 1997, the volume of imports was greater than exports by 121,129 mt, however, the value of fish exported exceeded imports by US$ 441.1 million.

In spite of the rich fishery resources of the country, most fishing communities live in poverty. A survey by National Statistics in 1992 revealed that 95.3% of 718,267 fishing families belong to the low-income group (Herrin and Racellis 1992). Poverty among fishers is directly caused by widespread degradation of marine and coastal resources (Lacanilao 1989), low (formal) education, lack of skills for alternative livelihoods, and no political empowerment (Agbayani 1995).

Seafarming in the Philippines

The vast coastal waters of the Philippines are conducive to seafarming activities. Seafarming has been identified as an appropriate fish culture technology because of its simple technology and low investments in well chosen sites. However, it is considered to be high risk because of natural disasters such as typhoons, red tide, diseases and uncertainty of fish seed. Seafarming or mariculture production in 1998 reached 681,397 mt. Seaweed production comprised 97.8%, and the rest was from oysters and mussels. Cage culture in fresh and marine waters totaled 30,566 mt, 96.67% of which was tilapia.

Grouper production in fish cages totaled only 33 mt. This low production is mainly attributed to lack of fry and fingerling supply. Researchers at SEAFDEC Aquaculture Department are making headway in the development of grouper breeding and hatchery technologies to address this problem. Researchers study ways to refine and increase grouper survival so that entrepreneurs can get into the hatchery business (Castanos, 1999). The sources of grouper and snapper fry/fingerling in the Philippines are shown in Figure 1. Fish cage and pen farming in marine waters and other seafarming practices in the Philippines are listed below.

Species	Cage/pen specifications	Culture specifics
Milkfish	rectangular marine pen, 20 x 50 x 6 m (1000 m2 x 6 m); wood, bamboo, polyethelene net	stocking density is 30,000 weighing 10 g; feeding with commercial pellets or crumbles, given 3x daily to satiation, and with FCR of 1.77; 138 days culture period, 94% survival; production about 5 to 7 mt
	standard module is four units of 4 x 4 m cages or maximum of 12 x 12 m for fairly calm weather	stocking density is 10 to 30 fish/m^3. SD is 35 to 100 pcs/m3. Survival is 20 to 95%. Production is 15 to 20 mt for cages of 12 m diameter x 8 m deep.
Seabass	rectangular broodstock floating net cage 4 x 4 x 3 m installed with hapa net of the same dimension with mesh size of 0.4 to 0.6 mm as egg collector; made of bamboo, wood and 200 l plastic drums	stocking density is 60 to 80 fish/cage, sex ratio is 13 to 28 female to male fish; feeding with trash fish daily at 3 to 5% of body weight; culture period of 4 years; fish matured and naturally spawned; also demonstrates an efficient, simple and cheap egg collector (116 M eggs in one breeding season).
	2.5 x 2.5 x 1.5 m bamboo and polyethelene netting	stocked with juveniles; feeding with trash fish at 5% of body weight twice daily, with FCR of 3.6:1; 4 months culture period; growth rate of 4 g/day

Grouper	2 x 2 x 2.5 m or 3 x 3 x 2.5 m, bamboo, wood, or coco lumber, with empty 200 l plastic drums	stocking density is 120 fish/m^3 of size 13 to 15 c, (growout), 5 to 13 cm (transition). or 2 to 3 cm (nursery): feeding with dry pellets and minced trash fish (growout) or *Chlorella*, *Brachionus* and *Artemia* (nursery); FCR of 2.5 to 2.8:1 for dry pellets and 6.3:1 for trash fish; culture period of 1 month (nursery), 3 months (transition), or 8 months (growout); production of 500 to 800 g per fish

Other Seafarming Practices

Species	Specifications	Culture Specifics
Mud crab	pens in reforested mangrove areas of size 200 m^2 made of bamboo and polyethylene nets	SD is 200 to 400 crabs/m^2. Stocking size is 150 to 200 g. Feeding with trash fish 3x daily at 5 to 8% body weight; progressive harvesting every 20 days; survival rate is 85%.
	Rectangular cage is 140 x 70 x 24 cm divided into 18 compartments, made of bamboo	SD is 18 crabs/compartment, size 175 g; feeding with trash fish, soft-shelled snails, kitchen leftovers, mussel meat, animal entrails; feed given 2x daily at 5% of body weight; 10 to 15 days of culture (fattening); average weight gain of 110 g.
Seaweeds *Gracilaria*	1 x 0.5 x 0.7 m cages in a 4 x 6 m bamboo raft	SD is 500/m^2; 12 months of culture; growth rate of 16 g/m^2/day
Kappaphycus alvarezii	average farming area is 3500 m^2	SD is 0.5 kg/m^2; seedling production is 45 days; culture period is 60 to 90 days. Culture methods are hanging long-line and Fixed-bottom. Average production is 150 to 9300 kg/crop (dry weight)
***K. alvarezii* and grouper**	5 x 5 m floating cage	*K. alvarezii* seedlings cultured in cluster, vertically and horizontally using nylon Monofilament rope attached to the bamboo raft; 4 seedlings (400 g) tied at 25 cm spacing. 25 grouper juveniles stocked in the cage. Final eight of grouper =230 to 515 g 68% survival; 5 kg production
Oysters/ Mussels	6 x 8 x 8 x 5 m raft; hung on the raft; collector ropes (for spat) are hung 0.5 m apart. 1-meter rope can hold 5 to 15 kg of mussel.	Collector ropes for spat collection are Ropes are hung 0.5 m apart. 1-meter rope can hold 5 to 15 kgs of mussel

A relatively new enterprise is the offshore fish cages for milkfish in the provinces of Pangasinan and Batangas. The "Polar Cirkel Cages" from Norway are circular cages in two sizes: 12 m diameter x 8 depth and 19 m diameter x 12 m depth. They are made of pipes and use polyethylene netting with mesh size ranging from #12 to #17. Another type of imported offshore cage is the "Ocean Spar Technologies Sea Station Cages". This cage consists of tightly framed webbing supported by a central floating spar and a submerged steel rim. The spar is constructed of either galvanized or marine-coated steel. It is 15 m in length and approximately 80 m in circumference. The net is made of knotless nylon. The sea cage has zippered entries for easy diving access (De la Vega, 1998).

Community-based Coastal Resource Management as a Strategy

The Philippines is a world leader in adopting community-based coastal resource management (CBCRM) as a strategy for community development. Government agencies, NGOs, academic, and research institutions create and implement CBCRM projects, usually as a collaborative undertaking of two or more agencies. The Local Government Code of 1991 and the Fisheries Code of 1998 provide the legal framework for CBCRM programs (Agbayani et al. 1997).

CBCRM strategy focuses on people empowerment so that they can become active and responsible partners in managing and developing the coastal resources in a sustainable way. CBCRM is a bottom-up, people-centered approach to resource management in contrast to the centralized top-down approach. It is believed that since the communities are the direct users and primary beneficiaries of the coastal resources, they are potentially the best managers of the resources (Rivera-Guieb 1999).

People empowerment covers a wide range of actions including:

- Enhancing community access to and provision of social services like health and water
- Ensuring community participation at all stages from program design to evaluation and monitoring
- Developing critical consciousness or consciousness-raising of the people through their own analysis of and reflection on the causes of their poverty and the socioeconomic structures and processes that affect their lives, and
- gaining control of the use and management of community resources. The people through their organizations are represented in the decision-making processes (Korten 1986; Rivera-Guieb 1999)

Pomeroy and Carlos (1997) reported the following types of intervention in 105 CBCRM projects and programs in the Philippines in 1984-1994.

Among the development interventions, the technologies for increased fish production had the third highest number of projects implemented. These technologies were aimed at increasing local fish production levels without engaging in capture fishing. There are three types of fish farming technology: mariculture sea farming; aquaculture or fishpond operation; and sea ranching. Some examples of mariculture include: seaweed farming, cage culture of tilapia, finfishes (grouper, snapper, siganids, seabass), abalon, lobsters, giant clams, urchins and pearl farming. Aquaculture includes the pond production of milkfish, spadefish, shrimp, prawns, mussels, and oysters. Sea ranching is a process whereby hatchery-bred fry are introduced to marine waters, allowed to grow and mingle with wild stocks of the congeners, and are harvested by conventional fishing methods (Munro 1991, in Pomeroy and Carlos, 1996). This is also called culture-based fisheries.

Transfer of appropriate technologies in seafarming for alternative and supplemental livelihood of fishers requires a participatory approach. The technologies should be simple, require low investment, and should make use of family labor. Preferably, raw materials for inputs (feeds, farm structures) should be locally available.

Development Interventions in Community-based Coastal Resources Management (1984-1994)

Type of Intervention	No. of Projects	Rank
Community organizing	52	1
Education, Training and Skills Development	48	2
Technology for Increased Fish Production	43	3
Alternative livelihood Development & Credit support	42	4
Artificial Reefs	40	5
Mangrove Reforestation	34	6
Protected Area Management/ Marine Sanctuaries	26	7
Resource Assessment and Monitoring	22	8
Resource Management Planning	14	9
Legislation/Policy Formulation	13	10

The Philippines Government Fishery Resources Management Project

The Philippines government through the Bureau of Fisheries and Aquatic Resources (BFAR) is presently implementing the 5-year Fishery Resources Management Program (FRMP) covering thirteen priority bays in the country. This program is a sequel of the completed Fishery Sector Program funded by a loan from the Asian Development Bank.

The FRMP has three major components:

- Fisheries Resources Management
  - Fisheries data management
  - Coastal resources management
  - Fisheries legislation and regulations
  - Community-based law enforcement, and
  - Nearshore monitoring, control and surveillance
- Income diversification
  - Community organizing
  - Micro enterprise development, and

- Mariculture and other enterprise development
- Institutional strengthening
  - Capacity building of BFAR and other government fishery agencies

Mariculture or seafarming is a major activity of the income diversification component of FRMP. The seafarming projects will be introduced and piloted in collaboration with research institutions and the private sector. The purpose is to develop these projects into sizable industries (similar to the seaweed industry), which can provide employment for coastal fishers over the long term. Support services for the livelihood activities shall be provided, including social preparation and technical assistance to the fishers' organizations. These include project identification and implementation, and training of coastal fishers in various aspects of micro enterprise. Financial assistance for identified viable projects shall be made available through various sources including the Fishery Sector Program Credit Fund and other government credit programs using the Grameen Bank approach.

Problems and Issues on Seafarming in the Philippines

There are several problems and issues that need to be addressed in order to ensure that seafarming is a sustainable livelihood activity. In terms of the technological and entrepreneurial aspects, the problems identified were:

- lack of feeds
- poor market linkages
- lack of fry and fingerlings
- ineffective technology transfer mechanisms, and
- access to cheap credit for small-scale operators

SEAFDEC Aquaculture Department is addressing the problem of lack of fry in its research activities on breeding of cultivable species (grouper, snapper, seabass, milkfish, mudcrab, tilapia, native catfish, carp, abalone), and ornamental fish (sea horses). Studies on alternative feeds for different species are also conducted to reduce dependence on trash fish with the inconsistent feed conversion ratio.

Problems related to the environment are:

- pollution caused by effluents of unused feeds
- disease outbreak resulting from poor farming practices
- pollution caused by run-off from denuded upland areas, and
- stocking beyond the carrying capacity of the ponds and other bodies of water

In addressing these ecological problems, government, communities, the private sector, research and academic institutions and other stakeholders should make an orchestrated effort.

The social and economic issues in seafarming are as follows:

- low (formal) educational level of fisher-beneficiaries
- high cost of inputs such as wild fry/fingerlings and feeds, and
- use of trash fish as feeds that competes with human consumption

There are insufficient institutional arrangements in management of coastal resources at the community and local levels. Community and local government leaders do not have sufficient working knowledge of the policies on property rights and their implication in the use of state-owned coastal resources such as mangrove areas and municipal waters. There is no overall coastal resource management plan that will provide long-term protection and guarantee the protection of and fair return on investment in seafarming ventures.

Development Framework for Sustainable Aquaculture and Resource Management

In implementing seafarming community-based projects, a development framework will require reliable information on the socioeconomic and political attributes of the community; existing institutional arrangements; biophysical attributes of the coastal resources; and the characteristics of the fishing and aquaculture technologies practiced in the community (Figure 2).

The action plan will focus on the technology transfer mechanisms and adoption by the target beneficiaries. Research and academic institutions, non-government organizations and the private sector in cooperation with fishers' organizations can facilitate this activity. The target beneficiaries will actively participate in the technology transfer activities during project planning, implementation, monitoring, and evaluation. The role of the local government will be to formulate policies on property rights in order to ensure that the fishers' organization can have access to the coastal resources on a long-term basis. The investment of the fishers will be protected if there is a guaranty from the local government on the long-term use of the coastal resources.

The security of the investment in terms of property rights on the coastal resources will encourage the fishers to act collectively to ensure a continuous flow of benefits. In the long term, the success indicators will be measured in terms of technological and economic efficiency, environmental sustainability and social equity.

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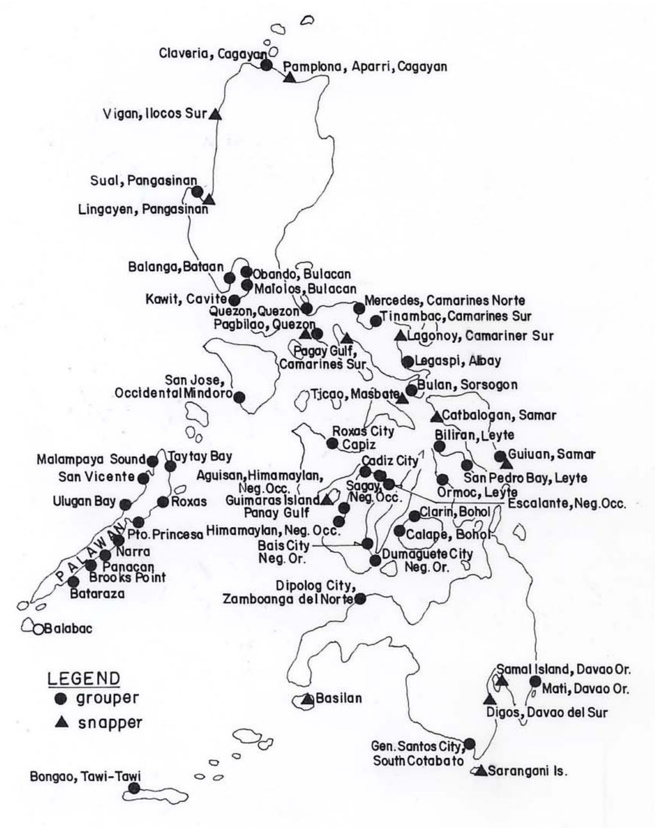

Figure 1. Known sources of grouper and snapper fry/fingerlings in the Philippines

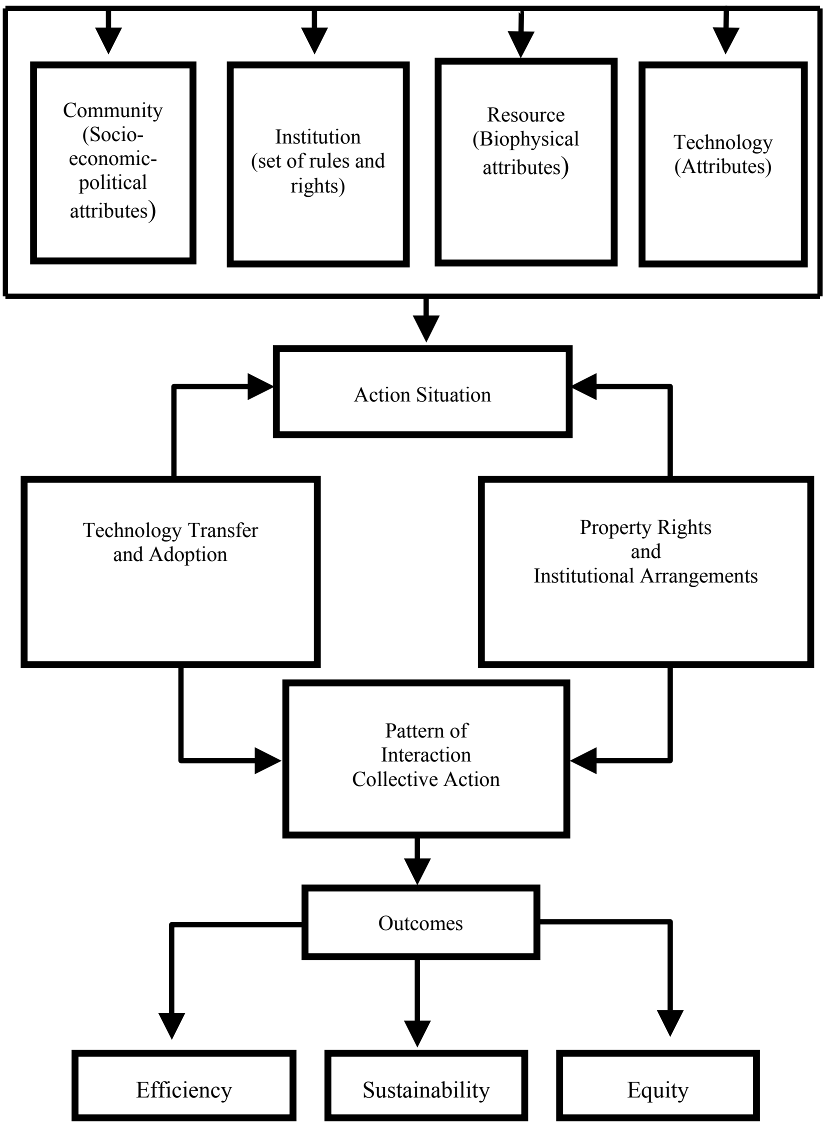

Figure 2. Framework for Sustainable Aquaculture and Resource Management

Managing Aquaculture Sustainability using Input-Output Relationships

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Abstract

This paper describes the Bay of Bengal fisheries activities, the important of using fisheries input-output relationships to manage fisheries sustainability. The important of information and knowledge for sustainable fisheries and aquaculture is strongly emphasized by the author. The paper looks at various factors on sustainability such as consumer-drive, and social and community bases for sustainability.

Background and Introduction

Many factors contribute to deterioration of our fisheries that are an economically valuable renewable natural resource. In aquaculture, for example, many solutions have been tried to solve the on-going malaise faced by the industry. However, the problems still persist. As there are no more so-called obvious solutions, the problems are to be re-examined and more creative and imaginative solutions developed.

This paper examines input-output relationships to uncover possible solutions for the industry. The industry is well advised to heed the pressures from environmental or green advocacy groups, many of whom are well-intentioned. By the same token, these groups must be realistic.

There is lack of serious attention to holistic or integrated management of the farm and environmental protection of the resources. Past aquaculture development was not planned and implemented to manage and protect the resources outside their immediate properties. Development of aquaculture was mainly concerned with increasing and expanding output and productivity, including profits.

The benefits of shrimp aquaculture were over estimated. The costs of social displacement and disruption and environmental degradation from untreated effluent into the waterways were not taken into account. Resistance and opposition to aquaculture, in particular shrimp aquaculture, will remain as long as the industry does not change its practices. To continue shrimp production, the industry has to convince and win over the anti-shrimp lobby.

Aquaculture development did not include holistic management in the true sense of the word. Sustainability may be there but it was implicit and left on its own, mainly in the literature on fisheries science and management.

Management was carried out within a pro-development framework until the present "flavour of the month" promotion of sustainability. It is only recently that the development oriented framework has been re-examined and given a more integrated management oriented thrust. Limits to the present system of management are environmental and social.

Criticism is needed to ensure that lessons from the past are learned and not repeated. Research, experimentation and "just do it" actions are needed to further understand the management intricacies and dynamics of aquaculture processes and systems. The processes and dynamics of management today are more demanding as production is characterized by a rapidly changing technological environment.

Unsustainability is Human-induced

As long as resources are exploited, no natural resource or ecosystem can remain in a virgin state. Sustainability and development of natural resources is ultimately determined by humans. There are no more virgin resources, not least because of human's polluting way of life. The polluting way of life means an inability to live within our environmental means. Living beyond our environmental means is and has been shown to be clearly unsustainable.

The present management is no longer a response to problems arising from unsustainable development. A new beginning from awareness is on the rise. Absentee management must not be allowed to return once a physical management presence has been established in the local area. It is easy to revert to old habits once the system becomes routine.

To work, management must be closely and routinely monitored. In addition to monitoring human behaviour and activities, it is necessary to monitor the resources and their habitats and ecosystems. Such monitoring can be facilitated if appropriate criteria and indicators of sustainability or measures of performance are available.

Monitoring Management with Performance Criteria and Sustainability Indicators

Performance criteria and sustainability indicators should show that the fishing communities are exploiting the fisheries they rely on for their livelihood. Sustainable or unsustainable fishing or fish farming can be examined by studying the resource and habitat status, conditions, patterns and trends in resource use, yield performance and ecosystem health of the fisheries, as well as the socio-economic well-being of the fishing and farming communities. These factors can be determined through the identification of species or ecosystems that are heavily exploited and endangered.

Management is the means to attain the goal of sustainability. The indigenous knowledge and experience of the fishers and other coastal resource users can be tapped to facilitate management of the resources. Fishers can be managers and not just fishing labour. When they are adequately trained in monitoring the indicators of sustainability, their feedback is invaluable to access the actual conditions of the resources and habitats on the fishing grounds or at fish farms. This is especially beneficial as these fishers are on the fishing grounds or at fish farms all the time in contrast to research and scientific or management personnel, who are not always in the field or on the ground. Fishers and other coastal stakeholders can provide early warnings to the scientists, researchers or managers of any "out of the ordinary" phenomena or observations.

To be effective in monitoring management, sustainability indicators must be simple, easy to understand, especially by the non-scientific community (fishers or fish farmers) and readily observable without instrumentation or laboratory work.

Bay of Bengal Fisheries

Sustainability criteria and indicators can be addressed by a closer and in-depth understanding of the problems, factors and causes of unsustainability in fisheries exploitation and development. Without reference to them, the criteria and indicators developed would not overcome unsustainable production. It can be shown that their system of fishing or farming is unsustainable through the examination of the sustainability indicators or performance criteria. Remedial measures or corrective steps can then be taken to foster sustainable fishing or farming.

The coastal resources and fisheries management issues and problems of the Bay of Bengal countries are no different than those of the other coastal states. They face more or less the same problems and constraints, which are:

- Reduced or stagnating earnings from fishing or fish farming
- Growing excessive capacity in seafood processing and cold storage facilities
- Over fishing arising from too many fishers (overcrowding) and fishing boats (over capitalization) chasing after too few fish (over exploitation)
- Continuing widespread use of indiscriminate and destructive fishing gear and other advanced harvesting technology (fish finding and aggregating devices)
    a) continuing upgrading of fishing efficiency through advances in technology
- Continuing rapidly dwindling fisheries resources, especially in coastal waters, which account for a dominant share of total catch (in some countries, 80 to 90% of the landings)
- Growing degradation of coastal waters and habitats from largely unmonitored pollution from point and non-point sources
- Reduced fish catch symptomized by:
    a) landings of more juvenile or immature fish, gravid females and mature males
    b) fewer landings of previously preferred and valuable species of food fish
    c) more landings of species previously considered trash fish but now of commercial value
    d) continuing indifference to coordination among stakeholder agencies, institutions and groups
- Continuing illiteracy of fishing communities and apparent inability to mobilize and organize themselves
- Continuing conflicts and inaction arising from overlapping government jurisdictions, multi-resource use, user pressures and conflicts in the coastal zone and fishing grounds
- Habitat and environmental degradation and impairment (reefs, seagrass beds, estuaries, mud flats, mangroves) from unplanned and uncoordinated water and land use. These include water turbidity, sedimentation or siltation from deforestation, aquaculture development and land re-landscaping (resort and other tourist facilities development), offshore oil drilling and refinery installation, harbour congestion and expansion
- Incompatible and inconsistent objectives in fisheries development planning, and management not integrated into the development process. For example:
    a) fisheries planners continue to project higher and higher per capita consumption of fish, further fueling pressures on remaining stressed stocks
- Continuing heavy reliance on wild seeds for aquaculture stocking

- Shrinking government sector to finance management

The high dependency of the Bay of Bengal (BOB) countries on fish for their food and livelihood security urgently requires management of the remaining increasingly precarious resources in the Bay waters and adjacent seas. In many countries, certain species of fish have already become extinct or are scarce.

Using Fisheries Input-Output Relationships to Manage Sustainability

As in any production process, production involves management of the input-output relationships of the production system. By improving management, the performance of the production system improves. Without understanding such relationships, the production processes, practices or techniques are not assisting in decision-making, affecting the production system and its performance in a sustainable manner. The aim of any production or enterprise is to stay in business. The barriers to entry in fisheries are relatively clear. Business concerns for sustainability are not explicit or clearly spelled out.

Until recently, many businesses or production endeavors emphasized profit maximization over sustainability, even though it is the sustainability of the business which must be emphasized. The science of management was mainly oriented to maximizing output and profits, not sustainability. Our modern environmental woes can partly be traced to the seduction of profits or profiteering and indiscriminate or irresponsible technology, pushing nature's carrying capacity to the extreme.

When such businesses became unsustainable, going out of business was an easy choice. Little concern was given to the abandoned business. No effort to restore, revive, rehabilitate or repair the damage inflicted on the production site and its surrounding environment or ecosystem by the business were made.

Sustainability is achieved when resource exploitation and input or factors of production are applied responsibly and judiciously within the limits of the carrying and holding capacity of the production or resource system, and as technologically recommended. In other words, the technology and carrying capacity are not taxed to their limits (for example, limit reference points of the precautionary approach to management).

The physical techno-economic input-output relationships can pinpoint the scope and areas where improvements in the performance of production or resource systems can be obtained. Inefficiencies do occur, which can lead to under performance or in the case of fisheries over exploitation. Exceeding the production system's carrying and holding capacity and its rate of regeneration or growth also occurs when production intensification and extensification are blindly carried out as has happened to date. The blind use of technology occurs when recommended inputs of production are employed in catching fish or producing fish without reference to the responsible use of the technology or based on sound technological recommendations.

While managing the use of inputs of production, the production of the output of the goods and services (of the ecosystem) must not be pushed to the extreme. Input and output control are needed to ensure system productivity, stability and sustainability. While the emphasis is on stable and sustainable production and productivity, humans must learn how to share. It is not just to produce more but to share the higher production in a more equitable way so that the poor have access to food or be able to buy food.

Information, Knowledge and Sustainability

Adequate information is necessary and vital for sound decision-making. Without adequate, timely and reliable information, production decisions are made in a vacuum. Because of poor or wrong decisions, production stability and sustainability are affected. The information, which can be obtained from an in-depth knowledge and understanding of the input-output relationships, can improve decision-making in fisheries relationships. So far, explicit concerns for sustainability based on the information obtained from such relationships have not been used to promote sustainable production.

While unsustainable exploitation is not acceptable, can we live with some degree of non-sustainability? Can non-sustainability be reversed at a later stage of development? These are knowledge and information gaps. The criteria and indicators being developed by this Seafarming and Grouper Culture Management Workshop are expected to provide some answers.

Looking to the Future: Consumer-Driven Sustainability

We have looked at sustainability indicators from the production or supply side. We now turn to the consumption or demand side.

We live in an increasingly fish-hungry world. Prices of fish and seafood continue to increase due to growing demand and dwindling supply. In many ways, demand pressures and increasing prices should be welcomed as they translate into pressures for better management and conservation of the remaining resources on a sustainable basis.

We are paying the price of at least three decades of inaction on integrated management of our fisheries and other coastal resources. All over the world, consumers are increasingly taking to fish for its nutritional value and health benefits. Seafood is not only food for the rural poor but a preferred item of diet of the relatively well-to-do and health-conscious segment of the population (in the form of fish oil (omega-3) supplement in their diet).

While fish is still generally considered the poor peoples source of cheap protein, many of them have to compete very hard with the more financially successful people for the daily catch even in the most far-flung fishing villages as buyers are combing the most remote coastal areas for seafood.

The sad irony is that while seafood buyers are able to find the fish landed, the fishers living in the villages are not able to access public information and/or government development or technical assistance. Social services and amenities or even fisheries extension services are rarely heard of in these remote villages. Frequently, even fisheries information or market price information is inaccessible to them. Because of the lack of information, they are more vulnerable to exploitation by more informed buyers or fishing input suppliers. While buyers are able to search out seemingly inaccessible fishing villages for seafood, the ill-informed fishers find government services inaccessible.

Fisheries and coastal resources sustainability relies on sound judgment based on correct understanding on what is sustainable production and consumption. This requires timely and reliable information. Dissemination, public education and awareness leading to action are crucial. Informed decision-making on production and consumption should include the following issues:

Production Side

- what to produce
- when to produce
- where to produce
- how much to produce
- what inputs to use (should antibiotics be banned), and
- how to produce (technology, should small mesh nets be banned)

Consumption Side

- when to buy (closed season)
- where to buy (from sustainably managed fisheries)
- what price to pay (higher prices for eco-labeled products), and
- what to purchase (endangered species, juvenile or gravid females)

These issues are crucial to management of the resources for sustainability and economy. Answers to these basic questions can be found in the input-output relationships of fisheries production as embodied in the technology, and consumer preferences and tastes. Market prices send powerful signals to producers and market intermediaries that the business as usual attitude has to be changed for sustainability. More fundamentally, as we enter the new millennium, customers will increasingly have a stronger influence on whether fish is to be produced by capture or culture. These emerging trends in responsible purchasing behaviour need to be heeded by producers and market intermediaries. The new consumers, generations of young people entering the markets, will be more and more influential as they will not only vote with their purchasing power but also are guided by their environmental conscience (having been brought up and trained in environmental education).

The large seafood companies and supermarket chains are now managed by younger and younger people, who are environmentally attuned and who can and will exert their influence in the market place. They will ensure that fish and seafood are procured from sources that are sustainably exploited and managed. Sustainability as a way of life is to stay in our new age knowledge-based global economy. We have to prepare for it, the sooner the better. This paper and the workshop technical consultation aim to contribute to this preparation.

Management Goals and Indicators of Sustainability

Performance criteria and indicators of sustainability are required to measure and predict the likelihood of sustainability and social and community well-being derived from the vast awareness-building effort and management intervention undertaken by the Bay of Bengal Programme (BOBP), and its member countries. It is first necessary to determine the goals of management. These goals must be based on standards of performance we wish to attain over time.

Consideration must be given to identifying and developing tools for operationalizing and implementing management activities to achieve the desired goals. These tools are translated into quantifiable or measurable criteria and indicators in the form of biological, physical, chemical, bio-physical, bio-chemical, ecological social, economic, socio-economic, political or cultural terms. In turn, they can be defined as site or local specific criteria and indicators. This paper is restricted to exploring the predictive socio-economic indicators of sustainability. These indicators point to tendencies of probable sustainability if many of the conditions and activities or actions are taken or presented and conscientiously carried out by the stakeholders. Progress towards sustainability is within reach when these are fulfilled. Used in combination and integrated into more rigorous and robust indicators, they can assist resource managers to monitor and evaluate the system's sustainability.

Interesting implementation tools include the management attainability analysis, sustainability attainability analysis and M&E-based impact assessment of so-called “objectively verifiable” indicators. For this analysis, the comprehensive specification of sustainability indicators is critical.

Social and Community Bases for Sustainability

The starting point to examine prospects for sustainability is the well-being and welfare of the communities relying on the resources for their food and livelihood security. If the well-being and welfare of the community are characterized by "living hand-to-mouth", their caring and protective attitude towards their source and means of livelihood will naturally be different from that when a more stable and higher standard of living and well-being is achieved. A caring protective attitude towards the environment and the resources does not come from a hand-to-mouth existence or an empty stomach. Hunger does not know nor care for sustainability.

To achieve sustainable management and conservation of fisheries and other coastal resources, appropriate criteria must be developed to monitor and evaluate established, prevailing or emerging resource use trends and patterns, as well as the interest, willingness and commitment of the people or community to carry out sustainable development and management of their resources. As pointed out earlier, the ultimate determinant of sustainability is human behaviour, including their "polluting" way of life. Without fishing, and pollution, fish can take care of themselves. Community action is clearly needed over and above individual actions. Individual actions have limited scope. Unless individuals in the community act in concert and together as a community, actions taken by each individual cannot amount to much. Action by the community is all encompassing.

Community Harmony, Bonding and Sharing

The absence or presence of resource use and user conflicts is indicative of growing pressure on an increasingly unsustainable or declining resource base. Communities of resource users are able to co-exist peacefully when there are enough resources to support them. As soon as the resources are limited, conflicts occur, The conflicts reveal that the resources are no longer sustainable. As a result, community harmony breaks down.

Every person has ideas, vision and priorities. Unless these are “communalised”, no amount of work on improving the community welfare and quality of life will result in tangible positive impact and benefits. This is especially true for communities which have been bypassed or excluded for generations and which have now become individualised, impersonal and selfish (the community spirit or sense of community has slowly eroded). Once a community of stakeholders share an idea, a vision and a priority, bonding develops and grows into a shared sense of community action for self-help. If a problem is serious, the shared sense of urgency is even more obvious. The people and their community must realize their collective vulnerability due to:

- lack of information
- negative impact of free market and economic forces, and
- continued isolation, bypassed by mainstream economy

To generate this community bonding, awareness-building on collective responsible behaviour is essential.

Fisheries and coastal stakeholders, social activists, environmental lobby as well as the GO and NGO development proponents are unified in wishing to protect, restore and enhance the biological and ecological diversity of our waters, land and natural resources. They differ only in approaches, time frame and priorities (based on their vested interests and agenda). Shared vision and priorities for management are slowly given more prominence as consensus is forged and agreement reached on such ideas, visions and priorities. There is a growing convergence of interests and perceptions on what needs to be done.

Theory of Club and Participation

Community bonding and closer stakeholder relationships can be fostered through visible and tangible activities and well publicized campaigns. Community-based activities should capitalize on this human desire to belong and to bring the community together. To ensure this, excitement must be built in, and a club mentality developed (clubs keep non-members out and everyone wants to get in and belong).

Caring and Protective Attitude and Behaviour

A good proxy measure or predictive indicator of sustainability is the caring and protective attitude of the stakeholders, mainly the resource users. We can measure such attitude and behaviour on a scale of 1-10; (1=not caring at all; 10=most caring), and (5= indifference).

The criteria used and weights (total 100 points) to measure the caring and protective attitude of the resource users can be as follows:

a. awareness on needs benefits and approaches to fisheries and aquaculture management as exemplified by the following actions (30 points)
   For Fishing:
   i. use of recommended mesh size in fishing gear (20 points)
   ii. observing other fisheries management measures, rules and regulations such as keeping to designated fishing zones and closed seasons and areas (10 points)
b. number of arrests for violations of fisheries management measures, rules and regulations (50 points)
c. influence of other resource users to comply with fisheries management measures, rules and regulations (20 points)
   For Fish Farming:
   i. use production inputs based on an analysis of input-output relationships of the production system and not on the sales-driven recommendation of the supplier of the input (100 points).

If fishers and fish farmers are not persuaded that there is a need for management, there is a greater tendency or inclination to break the law. Thus, the number of violations and/or arrests can be a proxy indicator of the livelihood pressure to bring a catch in by whatever means, including breaking the law. There is a causal relationship or link between poverty and non-compliance with management rules.

We can quite safely conclude that the more stakeholders in a population are attracted and converted to be more caring and protective of the environment, with a score of 6.0 and above, on our scale of 1 to 10, the greater is the probability that environmental and resource sustainability is attainable within a time-bound awareness building and action campaign. This caring and protective attitude and behaviour are taking root in many countries, especially among the younger generation that are trained in environmental science and responsible stewardship of the environment. When the entire community adopts this caring and protective attitude and fish responsibly as embodied in the Code of Conduct for Responsible Fisheries (as it is steadily observed in Phang-Nga Bay's 114 fishing villages), the Bay fisheries is well on the way to sustainable exploitation. Illegal push nets are given up for burning and the Department of Fisheries replaces them with gillnets and other less damaging gear with appropriate mesh size.

Community Participation and Commitment

The long overdue focus on involving and increasing the role and contribution of the fishing communities in the use and management of fisheries and coastal resources is crucial to the sustainability of the fisheries and its ecosystem. The active consultation with and solicitation of the views of the stakeholders in the fisheries is required. Management of the fisheries with the active participation of all the stakeholders will ensure successful compliance. Enforcement of regulatory and management measures may not be necessary as the fishing communities and other stakeholder groups will identify with the restrictions they planned, designed and imposed on themselves.

As another illustration, restoring fisheries habitats or a fishing ground is a long and costly proposition. Individuals can initiate such an activity. However, unless the whole fishing village community supports these individuals, the effort will not succeed as well as if the community helps in the restoration work. Intervention in management must be 'communalised'. Since we have impaired or destroyed our natural coral reefs, we now build artificial reefs. The proper use of artificial reefs for resource management can be achieved if community members cooperate and do not use it as a fishing gear to concentrate the fish for ease of netting them.

Denuded seagrass beds and mangroves are being replanted and kept off-limits. Fishers are enjoined not to go through the replanted seagrass beds during low tides to help them regenerate faster. Community spawning cages are constructed in strategic locations for fishers to drop off gravid swimming crabs to allow them to spawn. Crabs are then sold and proceeds used for community improvement activities. Fishers actively participate in the community open water stock enhancement through the bimonthly release of hatchery-produced finfish and shellfish seeds. A working indicator of sustainability is the community turnout, participation and financing of such activities. Although the community turnout is at present excellent and funding of these activities is externally-driven, the ultimate test of sustainability is the degree of cost-sharing between the government and the fishers. Success is ensured when the community assumes the full responsibility for financing these investments.

No resource management can be completely participatory; government assistance and its enabling and facilitating role in community actions are still needed. The purpose of resource management is to create an environment where the resource users with the help of the government adopt sustainable practices. Making the voice of fishers and fish farmers heard, and matter in government decision-making and intervention in fisheries is well founded. A possible indicator is the ability and capacity of the community to mobilize themselves for self-help.

Community Bonding

A key criteria and indicator of community and social well-being is the relationships between fishers and their money lenders and market intermediaries. These relationships which perpetuate economic hardships and social dependence of the fishers on the financers and market intermediaries. These relationships are well-entrenched and difficult to dismantle. Governments have attempted to provide alternative sources of credit, frequently at much lower interest rates, as well as alternative marketing outlets and channels such as marketing cooperatives to the existing predatory ones but they all have failed. These social relationships, which perpetuate economic hardships and social dependence need to be examined by social scientists to break-up such ties or lessen their burden. The assumption is that such relationships are detrimental to the well-being of the fishers and all market intermediaries in the long-run. When fish supply runs out, there is nothing left for the intermediaries to market and distribute. Suppliers will not be able to sell nets to fishers or lend money to the poor. Everyone loses, in the end.

Preliminary field surveys and studies from Indonesia have revealed that relationships that perpetuate economic hardships are slowly breaking down and becoming more symbiotic as the older generation is replaced by a more informed younger generation of fishers, money lenders and middlemen. It is prudent to include the money lenders and middlemen into the management scheme instead of alienating them. Exploitation of fishers by money lenders, middlemen and merchants is steadily decreasing in developing countries such as Indonesia.

An indirect measure of probable sustainability is the degree of indebtedness of fishers to money lenders and market intermediaries, including their freedom to sell their catch to the highest bidder. These two indicative measures translate into reduced pressures for the indebted fishers to fish at whatever cost, using destructive gear and traps not only to feed their families but to repay their debts under pressures from money lenders and middlemen.

If and when fish buyers willingly compensate fishers for their fish and effort commensurate to their value or market worth, fishers and fish farmers can get out of their hand to mouth existence. The key is remunerative compensation.

Although this is a formidable change, these social and economic conditions are not impossible to attain, especially when fishers and fish farmers engage in direct selling as many of them are starting to do (for example, in Malaysia).

Decline in family size and reduced illiteracy are additional parameters to examine in working towards sustainability of resource exploitation. Information and awareness building is important in informing and educating people so that they correct past mistakes.

Development history has shown that no country has been able to alleviate or eradicate poverty or improve living conditions for its population by relying on a single sector (fisheries, forestry or agriculture). The sustainability indicator for improved community well-being and welfare is the degree of integration of the different sectors in the rural economy. Durable sustainability must seek solutions from other sectors. Solutions to fisheries or aquaculture sustainability problems can also be sought outside of fisheries. Sustainability in over-crowded and over-capitalised small-scale fisheries or aquaculture implies the direct withdrawal of this concentrated effort. Alternative employment and/or income opportunities must be provided or found. Without these opportunities, people will stay with the fisheries and the problems will continue. Until and unless these opportunities are provided to them, sustainability of fisheries will not be attained because the fishing pressures remain (and not just fishing pressures but destructive fishing pressures).

The growing interest in greater intra-government and inter-department coordination in planning and implementation is a good indicative measure that sustainability in resource exploitation is promoted.

Less Pollution Indicator

Production, consumption and other human activities must create less pollution and material waste. Attachments to materialistic life styles must and can be re-examined and re-oriented. This can be accomplished through managing technology and know-how. Technology is largely neutral when it is responsibly used. However, individuals with uncaring profiteering attitudes can abuse it for short-term gains. In addition to responsible producer behaviour, consumers can also contribute to sustainability. Capping consumption levels on a per capita basis will reduce not only demand for increasingly scarce goods and services but also lessen pressure on remaining stocks and reduce pollution.

Indicators can be developed to trace and measure the sources, types and amount of material waste and pollutants generated by a fishing or fish farming household of x number of family members in the family's daily production and consumption activities. It is conservatively estimated that one kg of waste is generated by a person. If this waste generation can be reduced by 25% to 50%, our habitats and environment will be subjected to less pollution hazards. In Phang-Nga Bay, waste disposal bins and incinerators are being provided to the fishing villages to contain such waste from polluting the water bodies. By tracking such indicators, it is possible to work towards reduced pollution and achieve reduced environmental degradation and impairment of fisheries habitats and ecosystem.

Summary and Conclusion

Fisheries are different from industries that depend on fixed stock resources such as mineral or oil deposits. Fish is a renewable resource and can be made sustainable through prudent management.

The problems in the BOB countries and the solutions are no more different than for the other coastal states. The need is to "just do it" as the Nike ad implores us. Unless we do it, we will not learn or gain any experience. It is crucial to experiment with any ideas to see if they work. For management to work, it has to be carried out and not left on the books or drawing board. This is demonstrated in the collective experience of BOBP and its member countries.

The business of any business is to stay in business. To remain in business, it has to manage its business on a sustainable basis. Management is the means to ensure sustainability. Thus, managing the input-output relationships of the production systems and businesses will promote sustainability, especially on the environmentally friendly use of inputs or factors of production. On the demand or consumption side, each consumer should consume according to need and not conspicuously and wastefully.

Fisheries and aquaculture management calls for long-term commitment to the solutions discussed in this paper. There is no shortcut to management for sustainability. Fisheries and aquaculture management effort is slowly developing in many coastal waters due to spreading aroused awareness. Awareness and knowledge are required to behave differently, to be responsible and take actions into one's hands.

The indicators of sustainability proposed in this paper can help to monitor the status, conditions and trends in the use of the fisheries and other coastal resources. These indicators are not independent or stand alone indicators and should be employed in combination with or integrated into other more rigorous and robust indicators. They provide the checks and balances, give advanced warnings on resource sustainability and draw attention to impending breakdown in sustainability (for example, disease outbreaks from poor water quality from pollution, declining stock abundance as exemplified by under-sized or immature fish).

The BOBP experience in community-based or community driven ecosystem oriented management of coastal fisheries has demonstrated that community bonding takes place when the interests of all coastal stakeholders are taken into account. This is because the stakeholders now feel ownership over the fishing grounds and aquaculture sites. The management action plan would be acceptable to them because it is theirs and is not imposed from outside.

For management to succeed, it calls for actions at both the individual and community or societal levels. By returning resource management decision-making to the local community, the government has not only empowered them as allies to manage their local area resources but also effectively transferred the cost of management. This is especially timely as the government sector is steadily shrinking. The tide has turned and communalised management is more readily accepted. With such communalised management, the caring and carrying capacity of the people and production systems will be enhanced. The lesson, which has not been learned and has to be learned immediately, is that benefits from aquaculture must be shared. Aquaculture must not only increase output of fish but also distribute the output more equitably to ensure a sustainable and stable future for the humankind. Sustainability must be defined in human terms.

Markets for Cultured Grouper and other Marine Finfish

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Abstract

This paper reviews the current trends for live seafood markets in the region, especially for seabass, grouper and snapper. Other market segments are examined including the opportunities for processed forms such as dressed, chilled and filleted fish.

Introduction

Seafarming of marine finfish in the region is a relatively young industry compared to shrimp or freshwater aquaculture. As it is still at the initial stages in many parts of the region, production levels are relatively low. The most popular species for marine culture in the region are Asian seabass (*Lates calcarifer*), snapper (*Lutjanus* spp) and grouper (*Epinephelus* spp). In the ASEAN countries, aquaculture production of these three species was 17,222 mt in 1997 (FAO, 1999) or 0.73% of the total aquaculture production in the same year.

As production is still low, the markets in the region are limited and mostly sold live through restaurants. Since the economic crisis hit Asia three years ago, trade of high-value fish species, including live seafood, has been declining. This is reflected by low restaurant sales and imports in major markets. As a result, prices of high-value seafood such as live grouper have been declining.

Market Trends

Grouper

Hong Kong and China

Hong Kong and the southern part of China are considered to be the main markets for high-value marine finfish such as live grouper. The Hong Kong Agriculture and Fisheries Department (AFD) estimated that in 1997, the consumption of live marine finfish was 27,735 mt. In 1998, however, the consumption dropped by nearly 15% to 23,603 mt. Further decreases in consumption was expected in 1999 as the imports of live marine finfish were lower than 1998. Based on the official import statistics, local production and industry sources, live grouper consumption in Hong Kong is estimated at around 5,000 to 6,000 mt per year (Pawiro 1999).

The main suppliers of live grouper to Hong Kong are Indonesia, the Philippines, Thailand and Malaysia. As a result of the economic crisis, demand and prices for most of the high-value live seafood, including grouper, have been declining. The reduction in the number of consumers dining out, as well as budget cuts for business entertainment, are the main factors behind the negative trends.

There is a concurrent decline in the imports of live seafood into Hong Kong. In 1999, volume of live marine finfish imports into Hong Kong dropped by 41.7% from the volume in January to October 1998. During the same period, the quantity of grouper imports decreased by 15.6% (Table 1). Even though imports of grouper increased in 1998, it was believed that most of the fish were re-exported to meet growing demand in the southern part of China. Besides the decreasing demand in the local market, the decline of imports of live marine fish into Hong Kong in 1999 was also due to lower re-exports into mainland China (more fish are being exported direct to China instead of via Hong Kong). The market size for live grouper in China is difficult to estimate as there is no official data available. Prices of live grouper in Hong Kong and Chinese wholesale markets are presented in Table 2.

Table 1. Imports of Live Grouper and other Marine Finfish into Hong Kong, 1997-1999 (Q = mt; V = HK$1000)

					January-October			
Species	**1997**		**1998**		**1999**		**1998**	
	Q	**V**	**Q**	**V**	**Q**	**V**	**Q**	**V**
Groupers	5 715.2	352 565	6 555.2	404 383	4 385.01	382 786	5 192.67	410 832
Wrasses	11.8	1 122	14.9	1 470	4.89	1 091	12.84	1 298
Snook and basses	1 346.1	27 338	2 001.2	37 739	1 708.5	27 975	1 650.21	31 103
Others	12 928.2	646 873	10 807.0	463 896	3 418.46	108 917	9 474.09	403 458
Total	**20 001.3**	**1 027 898**	**19 366.3**	**907 488**	**9 516.86**	**520 769**	**16 329.81**	**846 691**

Source: AFD, Hong Kong

Table2. Average Wholesales Prices of Live Grouper in China and Hong Kong 1999/2000 (US$kg*)

	1999											
Market/Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
China (Guangdong)												
- Brown spotted grouper	14.98	13.15	14.19	15.00	15.50	16.20	15.70	15.70	15.70	15.70	15.70	14.49
Hong Kong												
- Brown spotted grouper	14.34	15.57	14.84	13.53	14.90	14.93	14.52	14.02	14.68	14.68	14.05	14.50
- Green grouper	13.45	13.63	12.69	12.56	13.51	12.99	12.54	12.99	13.67	13.81	13.10	13.50
- Red grouper	37.17	39.82	34.40	37.17	33.98	33.27	36.10	36.63	34.83	32.92	33.45	34.00
	2000											
Species	**Jan**	**Feb**	**Mar**									
China (Guangdong)	13.29	12.80	13.53									
- Brown spotted grouper												
Hong Kong												
- Brown spotted grouper												
- Green grouper												
- Red grouper												

Source: INFOFISH Trade News/AFD, Hong Kong
Note: 1 US$ = RMB 8.28; 1 US$ = HK$7.77

Chinese Taipei

Chinese Taipei is a major market for live seafood, including grouper. The country is also the main supplier of grouper; thus the domestic demand is mostly met by local production. As Chinese Taipei is a net exporter, imports of the product for food are relatively small, at only 28.6 mt in 1998 (Table 3).

Table 3. Live Grouper Production and Trade in Chinese Taipei, 1995-1998, (Q = mt, V = NT$1000)

		1995	1996	1997	1998
Aquaculture production (mt)	Q	2 104	1 882	2 529	3 471
Export	Q	67	229	249	45
	V	892	5 294	8 005	1 530
Import*	Q	20	9.3	17.5	28.6
	V	3 567	1 832	3 500	6 436

Source: Chinese Taipei's Fisheries Yearbook, 1994-1998
*Note: * excluding grouper fry*

Southeast Asia

Singapore is another major market for live grouper in the region. However, for the last five years, imports of live seafood have been declining from 1,841 mt valued at S$9.7 million in 1994, to only 1,137 mt valued at S$6.2 million in 1998. Industry sources estimate that grouper constitutes around 15% of the total quantity of imported live seafood (Table 4).

Table 4. Imports of Live Marine Finfish into Singapore, excluding Fish Fry and Ornamental Fish, 1994-1998 (Q = mt; V = S$1000)

Origin		**1994**	**1995**	**1996**	**1997**	**1998**
Malaysia	Q	1 773	1 504	1 426	1 225	1 127
	V	9 075	11 199	9 421	7 717	6 110
Others	Q	68	45	40	6	10
	V	649	383	408	58	54
Total	**Q**	**1 841**	**1 549**	**1 466**	**1 244**	**1 137**
	V	**9 724**	**11 582**	**9 829**	**7 943**	**6 164**
Estimates of imported groupers ①	Q	270	232	220	187	171
	V	NA	NA	NA	NA	NA

Source: Singapore Trade Statistics
Note: ① the estimate figure is based on industry information that around 15% of imported live fish consists of grouper

It is worth noting that Singapore Trade Statistics do not include fish landed from Indonesian fishing vessels, which also bring in live seafood, including grouper. With the local production of around 100 mt, it is estimated that the market size for live grouper in Singapore is around 400 to 500 mt annually.

Besides the live form, grouper is also traded internationally in whole, dressed, fresh/chilled or frozen forms. These are mainly wild-caught fish as the supply is abundant and prices are much cheaper compared to farmed grouper.

In Southeast Asia, fresh/chilled grouper is sold through supermarkets mainly in dressed form. Brown spotted grouper is popular in Kuala Lumpur as it is cheaper and is sold in supermarkets. The fish is usually small, around 200 to 300 mt and is packed in plastic trays containing two pieces per tray. At the wholesale market in Kuala

Lumpur, imported chilled grouper is sold at around US$ 4.21 to US$ 6.00 per kg depending on sizes (Table 5).

Table 5. Average Wholesale Prices of Whole Fresh/Chilled Seabass, Red Snapper and Spotted Grouper in Kuala Lumpur, 1999/2000 (US$/ kg*)

	1999											
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Seabass	2.78	2.80	2.92	2.82	3.41	2.95	2.95	2.89	2.82	2.72	3.03	2.63
Red snapper	2.03	1.98	1.99	2.00	2.47	2.08	2.14	2.03	2.04	2.07	2.24	2.89
Spotted grouper	-	-	-	-	-	-	-	-	-	4.21	4.47	4.34
	2000											
Species	**Jan**	**Feb**	**Mar**									
Seabass	2.63	2.76	2.76									
Red snapper	2.89	2.76	3.03									
Spotted grouper	4.34	5.92	4.34									

Source: LKIM/INFOFISH Trade News
*Note: *) The original prices are in RM/kg which have been converted into US$ (1 US$ = RM 3.8)*

USA

The US is a potential market for processed grouper both in dressed and fillet forms. As domestic supply cannot meet the demand, a large quantity of grouper is imported into the US, mainly from the Central American countries of Mexico and Panama. Exports from this region (India, Indonesia and Thailand) are mainly in the frozen fillet form. In 1999, around 4,470 mt of grouper were imported into the US market, mainly in fresh/chilled form (Table 6).

Table 6. Imports of Fresh/Chilled & Frozen Grouper into the USA, 1997-1999 (Q = mt; V = US$1000)

	1997		1998		1999	
Products/Origins	**Q**	**V**	**Q**	**V**	**Q**	**V**
Fresh/chilled (air-flown)	**5 706**	**16 562**	**5 864**	**18 621**	**4 170**	**14 485**
Mexico	4 009	10 583	2 930	8 843	3 062	10 215
Panama	1 149	3 648	2 284	6 849	503	1 455
Indonesia	6	32	27	78	1	4
Frozen	**542**	**1 408**	**350**	**1 146**	**300**	**899**
Mexico	272	832	166	597	70	255
India	185	276	61	96	28	46
Indonesia	5	31	54	201	72	219
Thailand	10	48	22	92	44	163
Grand Total	**6 248**	**17 970**	**6 215**	**19 767**	**4 470**	**15 384**

Source: NMFS

Prices of chilled grouper fillets from Latin America range from US$ 3.50 to US$ 5.80 per lb c&f USA. Frozen grouper from India is exported at around US$ 1.50 to US$ 2.00 per kg c&f Europe for the gutted form and US$ 3.00 to US$ 3.50 per kg for fillets.

Seabass

The global production of cultured Asian seabass is around 20,000 mt, with the main producers being Thailand, Chinese Taipei, Malaysia and Indonesia. The current market for Asian seabass is almost exclusively limited to the Southeast Asian and Far Eastern countries such as Malaysia, Thailand, Singapore, Chinese Taipei and Hong Kong, China. Demand in Malaysia, Thailand and Chinese Taipei is met by locally-supplied product, while Singapore and Hong Kong, China import a significant amount of seabass annually.

Malaysia

The bulk of the farmed production is sold in live form through restaurants and hotels. The ideal market size for live seabass ranges between 600 g to 700 g/piece. In the catering trade, farmed seabass is among the preferred species in Malaysia, Singapore and Thailand. Malaysia exports a significant quantity of live seabass to Singapore and imports farmed seabass from the southern part of Thailand. With a production of farmed seabass at around 3,500 mt, it is estimated that Malaysia consumes at least 3,000 mt of farmed seabass annually.

During the last two years, restaurant sales have been declining due to the economic crisis. Accordingly, the price of live seabass declined in 1998-1999. In 1998, ex-farm prices of cage cultured seabass were around RM15.00 to RM16.00/kg (US$ 3.95 to US$ 4.20); the current price range is around RM13.00 to 15.00/kg (US$ 3.42 to US$ 3.95). For live seabass from earth pond culture, the current ex-farm prices range from RM10.00 to RM13.00/kg (US$ 2.63 to US$ 3.42/kg) depending on the type of feeds used.

Singapore

Singapore is considered a major market for lower-value live marine finfish such as seabass. It was estimated that more than half of the live marine finfish imported into Singapore is seabass, with Malaysia and Indonesia being the main suppliers. Local production of seabass in 1998 was only 235 mt, which is well below the market demand. An increasing amount of live seabass from nearby islands in Indonesia has been imported to Singapore, but the quantity is unknown. It was reported that NTUC Fair Price, a supermarket chain in Singapore, is introducing chilled seabass as a sales item and is expected to buy 2.5 mt of seabass per week. It is difficult to estimate the market size of seabass in Singapore, but it is believed that at least 1,000 mt of live seabass is consumed annually.

The market for fresh/chilled seabass is relatively small but is growing, especially for gutted-chilled seabass sold through supermarkets in the region. Wholesale prices of whole-chilled seabass in Kuala Lumpur are currently around US$ 2.80 to US$ 3.00/kg, while retail prices in supermarkets range from RM18.00 to RM22.00/kg (US$ 4.79 to US$ 5.79) for tray-packed chilled fish. The average wholesale prices of seabass are presented in Table 5.

It is also worth noting that Chinese Taipei has begun exporting processed seabass. In 1996, it exported only 11.6 mt of frozen seabass but in 1998, the figure increased to 247.3 mt. The main markets were Japan, USA, and Korea.

Snapper

Unlike seabass, snapper (*Lutjanus* spp) is available worldwide and traded in many parts of the world. The supply comes mainly from the wild; production of farmed snapper is still very low. According to FAO statistics, in 1997 production of farmed snapper was only 2,128 mt, of which nearly 78% was harvested in Malaysia. The species cultured in Malaysia is mangrove snapper (*Lutjanus argentimaculatus*), which is not in great demand by the Chinese community as compared to seabass. The bulk of the farmed production is exported to Hong Kong in live form.

Hong Kong is the main market for live mangrove snapper. In 1998, it imported 806 mt of mangrove snapper worth RM3.1 million (US$ 0.82 million) from Malaysia alone. During January to August of the last year, 512 mt were exported to Hong Kong from Malaysia (*Berita Perikanan*, October 1999).

However, Hong Kong's official statistics showed a lower import figure for live mangrove snapper than Malaysian statistics. Up to October 1999, imports of live mangrove snapper into Hong Kong were only 491 mt, of which 295 mt were from Malaysia. The other main suppliers of live mangrove snapper were Chinese Taipei and Thailand. Supplies from Chinese Taipei and Thailand into Hong Kong up to October last year were 70 mt and 126 mt respectively. Average wholesale prices of live mangrove snapper in Hong Kong ranged from HK$50 to HK $75/kg (US$ 6.5 to US$ 9.60/kg) during 1998/1999 (Table 7).

Table 7. Average Monthly Wholesale Prices of Live Snapper and Seabass in Hong Kong, 1998-1999 (US$/kg)

1998												
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mangrove snapper	6.68	6.81	7.20	6.94	7.62	7.58	7.58	8.10	7.84	8.10	8.48	8.35
Red snapper	8.48	7.97	8.61	8.35	7.58	7.71	7.71	7.71	8.48	8.35	7.97	7.58
Seabass	-	-	-	-	-	-	5.27	5.14	3.86	3.86	3.86	3.60
1999												
Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mangrove snapper	9.00	8.74	9.64	8.35	8.23	9.64	8.61	8.87	8.23	8.34	8.95	9.60
Red Snapper	7.71	8.17	8.48	8.35	8.35	8.87	7.84	7.71	7.46	7.63	6.99	7.50
Seabass	-	-	-	-	-	-	-	4.50	5.27	5.59	6.20	6.50

Source: Agriculture and Fisheries Dept./INFOFISH

A large proportion of processed snapper, almost all from the wild, is traded in the international market in gutted and fillet forms, both chilled and frozen. It is difficult to quantify the trade of processed snapper, as most countries, with the exception of the USA, do not include snapper as a separate product in their official statistics.

In the regional markets, fresh/chilled snapper is very popular. Whole fresh fish is sold through traditional wet markets, while supermarkets sell chilled red snapper steaks/portioned in tray-packs. The price of steak/portioned red snapper in supermarkets around Kuala Lumpur ranges between RM22.00 to 27.00/kg (US$5.8 to US$ 7/kg). Average wholesale price of whole-chilled red snapper is around US$2.00 to US$ 3.00/kg (Table 4).

Of the international markets, the USA is considered the main market for snapper, importing around 12 000 mt annually. The main items imported are chilled products, both dressed and filleted forms, mostly from Central America. In 1999, imports of fresh/chilled snapper (mostly air-flown) into the USA were 10,353 mt valued at US$35 million. Indonesia and Thailand were the main suppliers from the region. The share of imported frozen snapper, mostly in fillet form, is relatively low, only 1,219 mt (11%) but there has been in an upward trend. The bulk of the exports from the region, mainly from Indonesia, Thailand and Vietnam, are in this category (Table 8).

Table 8. Imports of Fresh/Chilled & Frozen Snapper into the USA, 1997-1999 (Q = mt; V = US$1000)

	1997		1998		1999	
Products/Origins	**Q**	**V**	**Q**	**V**	**Q**	**V**
Fresh/chilled (air-flown)	**11 000**	**37 239**	**10 067**	**34 659**	**10 353**	**34 872**
Mexico	3 545	11 373	3 266	10 474	2 468	8 090
Panama	2 812	8 493	1 752	5 342	2 645	7 359
Indonesia	41	202	109	445	145	665
Thailand	47	196	4	11	37	136
Frozen	**1 036**	**2 786**	**1 307**	**4 036**	**1 219**	**3 669**
Mexico	412	898	320	824	223	569
Indonesia	108	431	361	1 346	467	1 658
Thailand	39	140	12	40	7	19
Vietnam	12	39	1	5	12	9
Grand Total	**12 036**	**40 020**	**11 375**	**38 695**	**11 572**	**38 541**

Source: NMFS

Japan, Hong Kong and Singapore are also important markets for processed snapper, mainly fillets. No hard data is available on imports of snapper fillets into these markets, but it is strongly believed that the imports of frozen fillets originating from the region (Indonesia, Thailand, Vietnam and also Malaysia), mainly consists of frozen snapper (Table 9).

Table 9. Imports of Frozen Fish Fillets into Major Markets, 1996-1999 (Q = mt; V = US$'000)

	1996		1997		1998		1999	
	Q (mt)	**V (S$1000)**	**Q (mt)**	**V (S$1000)**	**Q (mt)**	**V (S$1000)**	**Q (mt)**	**V (S$1000)**
Singapore								
Thailand	1 326	3 527	1 405	4 208	1 219	4 448		
Vietnam	735	4 770	699	3 947	1 082	6 698		
Malaysia	773	3 753	989	4 512	892	4 956		
Total (incl. others)	**5 097**	**25 576**	**6 585**	**33 227**	**6 938**	**38 058**		
	1996		**1997**		**1998**		**1999**	
	Q (mt)	**V (¥ million)**	**Q (mt)**	**V (¥ million)**	**Q (mt)**	**V (¥ million)**	**Q (mt)**	**V (¥ million)**
Japan **								
Thailand	9 721	3 962	8 628	4 083	8 748	3 984	4 173	1 814
Indonesia	2 169	1 033	1 817	1 014	2 039	1 013	1 174	457
Vietnam	5 985	2 728	6 225	3 209	3 732	1 788	4 206	1 678
Malaysia	16	6	54	17	35	12	6	1
Total (incl others)	**83 124**	**35 230**	**90 477**	**43 936**	**86 241**	**41 335**	**75 609**	**37 494**
	1996		**1997**		**1998**		**1999**	
	Q (mt)	**V (HK$1000)**	**Q (mt)**	**V (HK$1000)**	**Q (mt)**	**V (HK$1000)**	**Q (mt)**	**V (HK$1000)**
Hong Kong								
Thailand	500	6 653	433	7 588	313	4 733	796	12 177
Indonesia	124	4 280	128	4 970	151	8 088	139	5 302
Vietnam	1 531	53 939	1 812	52 062	2 541	52 977	2 355	38 638
Malaysia	141	2 279	171	2 274	351	4 238	386	5 303
Total (incl others)	**16 346**	**569 866**	**17 521**	**684 759**	**11 557**	**337 494**	**12 498**	**330 934**

*Note: **) Excluding tuna and mero*
Source: National Statistics

Prices of frozen red snapper fillets in the international market are generally stable. The current price of frozen red snapper fillets from Indonesia is around US$3.05 to US$

3.75/lb, ex-warehouse NY, USA (Table 10). Prices of chilled red snapper fillets from Latin America range from US$ 3.50 to US$ 4.00/lb c&f USA. In the US market, fillets are marketed in skin-on and skinless forms.

Table 10. Prices of Frozen Fillet Red Snappers Ex-warehouse, NY, USA from Thailand/Indonesia, 1998 - March 2000 (US$/lb)

	1998											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
4 - 8 oz/pc	4.40	4.40	3.85	3.85	3.85	3.45	3.30	3.20	3.20	3.00	3.00	3.05
8 - 10 oz/pc	4.40	4.40	3.85	3.85	3.85	3.55	3.30	3.20	3.15	3.00	3.00	3.05
	1999											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
4 - 8 oz/pc	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.75	3.75
8 - 10 oz/pc	3.05	3.05	3.05	3.20	3.20	3.10	3.10	3.20	3.20	3.75	4.00	4.00
	2000											
	Jan	**Feb**	**Mar**									
4 - 8 oz/pc	3.75	3.60	3.60									
8 - 10 oz/pc	4.00	3.75	3.75									

Source: INFOFISH Trade News

Outlook

There are signs of economic recovery in the region such as positive economic growth, increasing foreign investments and stock market indexes. These indicators increase consumer confidence, which is expected to improve demand for high-value live marine finfish such as grouper, snapper and seabass. As the consumption of live marine finfish is very much associated with the catering sector, the economic recovery means more people will be dining out; thus, consumption of seafood is expected to improve. However, it will take at least two to three years after the economic recovery is complete to stimulate demand for high-value live fish. The most important factor for possible market expansion in the region is the fact that fish is not a luxury item for Southeast/Far East Asian consumers, but a necessity.

In the long term, diversification of markets and product forms is necessary. Even though the high-value live marine finfish market is important to the region, it is limited in the sense that it cannot absorb any expected sharp increases in production.

Assuming that there will be a breakthrough in culture technology in high-value marine species like grouper, snapper and seabass, we have to think of other markets and products to absorb harvest increases. It would be pointless to increase production without the proper marketing plans.

International market demand for processed and value-added convenience products is forecast to increase in the future. In serving this lucrative market, the key factor is cost efficiency; the industry has to produce products at a lower cost, thus increasing their competitiveness in international markets.

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Assessing the Sustainability of Small-scale Grouper Culture in Southern Thailand

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Abstract

The paper outlines a research proposal on accessing the sustainability of small-scale grouper aquaculture in Southern Thailand. It provides brief overview on social, ecological, economics and technical aspects on grouper aquaculture that will be studied during the research.

Introduction

The culture of grouper has been promoted in Thailand since the early 1980s as an alternative livelihood option for coastal communities. Grouper culture is currently based on the collection of wild seed derived from artisanal capture fisheries as hatchery production of grouper is still at the experimental stage. Grouper are a high value carnivorous fish, requiring inputs of trash fish in the absence of an alternative. The international market for live reef fish, which exhibits a high degree of price volatility, fuels demand for grouper production, and other high value marine fish. It is necessary to question the sustainability of this activity as an option for coastal communities. A three year project is currently underway to address this issue.

A systems framework will be used to assess sustainability, providing a holistic approach through the recognition of inter-linkages between system components at a number of hierarchies and scales. The culture of grouper is an activity that is embedded within a complex system of ecological, social, economic and technological dimensions. It is necessary to recognize that these dimensions, as components of a unified whole, are mutually influential, conferring change upon one another as they respond to external elements. Thus, the sustainability of any component or subsystem cannot be considered in isolation. These assumptions form the basis of the present study. The system will be assessed through a process of subsystem analysis. Five subsystems have been identified.

Social

The social subsystem focuses on the people involved in the grouper system, primarily those who rely on grouper culture and its associated activities for their livelihoods.

Ecological

The ecological subsystem includes all activities that have an influence on the ecology of the coastal zone. In the context of grouper culture, this includes the fisheries for grouper and the fishery for trash fish. Activities external to the grouper system but which in some way affect the fisheries directly or indirectly must be considered. The ecological subsystem also necessitates a consideration of grouper ecology based on secondary data and fisher knowledge, to assess the potential impact of the juvenile fishery on grouper stocks and ecosystem ecology.

Economic

The economic subsystem may be described at a number of levels of the system hierarchy, from the local scale of the production system to the macroeconomic scale of the international trade in grouper. This subsystem incorporates any aspect of the system related to the profitability of grouper culture, the grouper fisheries, and the market of grouper from the local production level, through middlemen, exporters, wholesalers to customers, market trends and influences.

Institutional

The institutional subsystem incorporates social and governance structures, which act within the system to determine resource allocation and use, and the inclusion or exclusion of members of society in certain income generating activities. Also of importance are the linkages between communities and higher government institutions through extension and provincial officers. In the context of the grouper system, it is important to identify government policy and actions related to the fisheries for grouper, the promotion of grouper culture, local extension work, the role of provincial fisheries officers, and community level fisheries organisations.

Technical

The dependence of grouper culture on wild seed and trash fish may be influenced by technology developments in hatchery production and nutrition. Important issues in the technical subsystem include developments in the hatchery production of grouper and pelleted food, and the likely uptake of new technology by farmers.

The approach is multi-dimensional and interdisciplinary, incorporating concepts of production system sustainability and economic viability, ecological sustainability and social sustainability. These concepts will be defined in the context of the grouper system.

Production system sustainability and economic viability

At the level of the farm unit, will production of grouper be sustainable and economically viable?

Social sustainability

Can grouper culture continue to provide a sustainable livelihood for coastal communities, able to withstand trends and shocks caused by subsystem perturbations? Will further development be socially acceptable?

Ecological sustainability

Will grouper culture undermine the integrity of the coastal ecosystem and ecology? Will it lead to the overexploitation of fish stocks to supply grouper seed and trash fish feed?

Stage one of the research methodology will comprise a situation appraisal using PRA techniques to identify provincial characteristics of grouper culture and fisheries activities in southern Thailand. A cross system assessment based on provinces selected from initial situation appraisal will form stage two of the project. The assessment will be conducted using PRA methodologies, semi-structured questionnaire surveys and collation of secondary data for analysis of livelihoods, markets and economics, natural resource use and coastal ecology, networks, institutions, production, and system input/outputs. Information integration and system analysis will take place in the final stages of the project leading to a holistic sustainability assessment and identification of system vulnerability.

Sex Reversal and Spermatogenesis in the Honeycomb Grouper, *Epinephelus merra*

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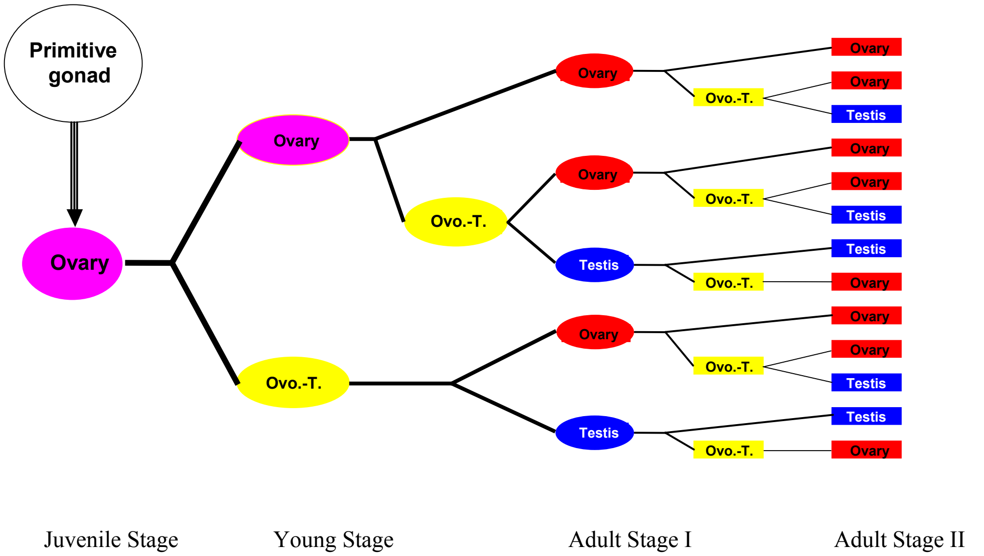
Abstract

Fishes belonging to the genus Epinephelus *(grouper) are protogynous hermaphrodites. It is believed that the sex reversal in groupers is affected not only by the size and age in each individual but also by the social relationships among individuals. The present study histologically examined the* E. merra *gonads of a range of sizes for evidence of sex reversal and spermatogenesis. One hundred forty-one* E. merra *(81 females, 44 transitional gonads, and 16 males) were collected by a hook and line around Sesoko Island, Okinawa, Japan, from April to November 1997. The gonads were fixed in Bouins solution, embedded in paraffin, sectioned at 6 um, and then stained with Mayers haematoxylin-eosin. Cross-sections of the gonads were viewed with a microscope-monitor system. The proportion of cross sectional area of the gonad occupied by each germ cell type from spermatogonia to spermatozoa. The histological evidence indicates that the sexual mode of* E. merra *is monoandric protogynous hermaphroditism. Total length ranged from 100 mm to 260 mm for the females, from 140 mm to 300 mm for the transitional gonads, and from 180 mm to 280 mm for the males. Ovaries with precocious sperm crypts (transitional gonads) were observed in some females. These sperm crypts contained all stages of spermatogenesis, from primary spermatocytes to spermatozoa. The percentage of gonad cross sectional area consisting of sperm crypts was higher in post spawning period individuals than in immature or mature period individuals. All samples examined had a vestigial ovarian lumen and sperm sinuses located in the dorsal part of the testicullar wall. Spermatogenesis with the germ cells in the various developmental stages from gonia to spermatid took place in April. Gonadosomatic index of males reached its peak in May and maintained high levels until July, suggesting that maturation of the males continues for three months from May to July. During these months, spermatogenesis and spermiogenesis occurred simultaneously in the testes, and the dorsal sperm sinus were filled with a large amount of spermatozoa. In November, lobules in the testes were mostly occupied by spermatogonia and the remnants of non-vitellogenic oocytes were distributed in the periphery.*



Flow diagram of sex reversal in grouper

Grouper Aquaculture in India

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Abstract

The paper reviews the present status of grouper aquaculture in India. In the field of marine finfish culture, India is still in the experimental phase only. Though a few experiments on the culture of Epinephelus tauvina *were carried out in nearshore netcages during 1985 and 1992 at Mandapam, concerted research effort in grouper culture was initiated only in 1996. Results obtained from experiments on growout production of* E. tauvina *and* E. malabaricus *in different culture systems are quite encouraging. Broodstock of grouper* E. tauvina *were developed by rearing fingerlings in captivity in 5-mt capacity FRP tanks at the onshore mariculture facility of the Central Marine Fisheries Research Institute at Cochin. Male broodfish were developed by sex transformation of fully mature female through hormonal intervention. Spontaneous spawning occurred several times in one year in the same 5-t FRP tanks, with fertilization and hatching rates of about 92% and 65% respectively.*

Introduction

The groupers (Serranidae, Pisces), widely distributed in the Indo-Pacific region, have very high market potential in the Southeast Asian countries and the middle east. Thirty-eight species of groupers are known (James *et al*. 1996) from the seas around India but only a few contribute to the commercial fishery. These fishes are abundant in the vast stretches of coral reefs and rocky areas distributed along the Gulf of Kutch, Malwan (Maharashtra), the Kerala coast, Wadge Bank, Gulf of Mannar, Palk Bay and the seas around Andaman and Lakshadweep islands. Almost the entire catch is taken from the inshore waters upto about 100m depth. The potential yield of the groupers (Kalava in Malayalam language) in the Indian EEZ is estimated to be around 54, 600 mt (Anon. 1991). The wide gap between the potential and the actual landings is principally due to the grounds being not amenable to trawls and set nets (Devaraj and Murty 1998). Groupers are highly esteemed food fish in many countries but the yield from the wild stocks is unable to meet the demands. Grouper aquaculture is in vogue in Singapore, Thailand, Malaysia, Philippines, Indonesia, Japan and Chinese Taipei for many years (Anon 1992). In view of the increasing demand for groupers in the export market, there is urgent need to step up production through aquaculture. Though India is the second major producer in Asia in the aquaculture sector (Asia contributes 84% in the world aquaculture production, FAO, 1995), finfish production from mariculture is almost nil. In the area of marine finfish culture, India is still in the experimental stage.

A review of the present status of grouper aquaculture in India is presented here, with the hope that this workshop would discuss the various issues and evolve suitable action plans for developing the technologies suitable for different hydro-ecological situations.

Status of Exploitation of Groupers in India

Hooks and lines and perch traps are operated in the inshore areas of Gulf of Mannar, Palk Bay and the sea off Kerala. *Epinephelus tauvina, E. malabaricus*, *E. undulosus, E. areolatus, E. merra, E. bleekeri, E. sonnerati, E. diacanthus, E. chlorostigma, E. fasciatus, E. faviatus*, *E. albomarginatus* and *E. lanceolatus* are common in the fishery. The experimental and exploratory fishing surveys conducted by various agencies reveal that the groupers are widely distributed in the Indian EEZ (Bapat *et al* 1982; Joseph *et al* 1987; Menon and Joseph 1969; Ninan *et al* 1984; Philip *et al* 1984). James *et al*. (1996) gave a review of the present status of the knowledge on these resources. The estimated annual average landings of groupers during 1990-98 is 11,200 mt. (Table 1).

Table 1. Estimated landings of groupers in India

Year	Catch (mt)
1990	4,718
1991	6,203
1992	8,548
1993	10,889
1994	9,444
1995	12,448
1996	14,688
1997	15,396
1998	18,570
Total	100,904
Average	11,212

Along the northwest region, fishing grounds for *E. fasciatus, E. malabaricus* and *E. lanceolatus* are located for trawling at depths between 50 and 360meters; the highest catch rate being 13.3 kg/hour from 91-125m depth. Along the southwest coast, between 8^{o} and 13ºN, at depths of 60-150m, the bottom with rocky and coralline outcrops forming extensive ridges, is rich in groupers; hence this region is referred to as *Kalava* ground. Handline operations along this coast yielded catch rates of 60-68 kg/hr. (Silas 1969; Oommen 1989) *E. areolatus, E. chlorostigma, E. diacanthus and P. typus* are the main species with highest catch rates during February. Based on the trawl survey in the Wadge Bank and Gulf of Mannar, Joseph *et al* (1987), Sivaprakasam (1986) and Sudarsan *et al* (1988) showed that groupers were more abundant at 20-50 m and 100-150 m depth, and their abundance decreasing beyond this depth. However, there is no targeted fishing for groupers except for the hook and line fisheries along Kerala and Tamilnadu coasts and the perch trap fisheries in the Gulf of Mannar and Palk Bay. Maximum catch of groupers is obtained along Tamilnadu coast (33.5%) followed by Maharashtra (27.8%), Kerala (21.2%), Gujarat (9.7%)(Fig.1). In the Gulf of Mannar, off Tuticorin about 250-300 country crafts with hooks and lines and gillnets operate in the 35-60 m depth zone, exploiting five species, of which *E. tauvina* is the most dominant (53%). Peak catches are taken during July-October (Mathew, 1994). Along the West Coast, off Cochin, the seasonal fishery for perches starts around December and lasts till March (Mathew and Venugopalan, 1990). Groupers form 90% of the catch, with maximum catch occurring in January. Off Quilon, in the 50-150m depth range there is a regular fishery by country crafts, using hook and lines during January-April; groupers form about 20% of the catch. (Madanmohan 1983).

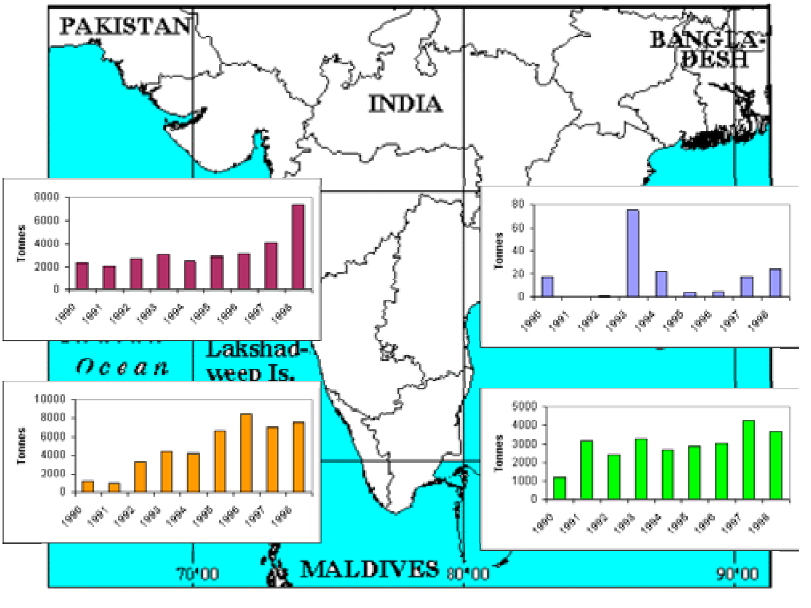
Export of Live Fish, Export Markets and Value

The demand for these species has led to their export in live condition mainly to the markets in Hong Kong, Singapore, Malaysia and Chinese Taipei. Very recently, a programme of seed survey and collection of commercially important groupers was carried out and very lucrative nursery grounds of grouper seeds (60-260 mm) were located off the Southeast coast of India and the production rate of live juveniles of *Epinephelus tauvina, E. malabaricus,* and *E. undulosus* were estimated at 10,647 kg per month (Rengaswamy *et al.* 1999). Based on this natural resource, M/s Scanet Aqua Exports Ltd. Tuticorin, a private enterprise operated netcages at Tuticorin in the Gulf of Mannar for captive holding and fattening and for live shipment to Hong Kong. About 20 mt of live groupers comprising of 3 species *E. tauvina, E. malabaricus,* and *E. undulosus* each fish weighing 2-18 kg were exported live. Efforts are in progress towards similar a venture in the Andamans.

Grouper Culture Potential

Cultivable species: The species are *Chanos chanos, Mugil cephalus, Liza macrolepis, Valamugil seheli, Siganus javus, S. canaliculatus, Sillago sihama, Epinephelus tauvina, Anguilla bicolor bicolor, Lates calcarifer, Etroplus suratensis, Oreochromis mossambicus.*

Fig.1 REGIONWISE LANDINGS OF GROUPERS IN INDIA



Possible locations: The inshore regions all along the Indian coast particularly along the regions of distribution of the species are suitable for mariculture using floating netcages, though location specific work is yet to be done, except for the experiments carried out by the CMFRI at Mandapam in fixed netcages in the nearshore waters. The

Chilka lake along the north east coast, the Pulicat lake, the Gulf of Mannar and the Palk Bay on the southeast, the Vizhinjam Bay, the backwaters along Kerala and Karnataka coasts, the Gulf of Kutch along the northwest coast, the shallow lagoons in the Andaman and Lakshadweep islands are available for pen and cage culture but their suitability for commercial ventures need to be studied.

Grouper aquaculture: Though experimental work on the culture of *E. tauvina* was initiated during 1985 and 1992 by the CMFRI (Table 2) at Mandapam (southeast coast), concerted efforts for studies on broodstock development, spawning, hatchery development and seed production were made only in 1996, by creating facilities and implementing the work.

- in ponds with tidal influence at Tuticorin
- in large 100 m capacity concrete tanks with sea water flow-through system at Mandapam
- in lined earthen ponds of 60-75 mt capacity with facility for sea water change
- in the onshore, 5 mt capacity FRP tanks with sea water recirculating system at Cochin

Table 2. Results of experimental culture of groupers in India

Reference	Species	Stocking Density	Growth/ Month	Production
James *et al.* (1985)	*Epinephelus tauvina* *E. hexagonatus*	13 (80 to 580g) 8 (190 to 80g)	87.3g 30.0g	
Hamsa and Kasim (1992)	*Epinephelus tauvina*	100/cage (5 x5x2m net cage)	-	288kg/11months (Mandapam)
CMFRI (1999)	*E. malabaricus* *E. tauvina*	$4/m^2$ (@ 65g --	775gm in 7months (Cochin) 1.26g/day (Mandapam) 40.8g/month (Tuticorin)	

Experiments on Grouper Culture

An onshore facility was created at the Mariculture Laboratory of Central Marine Fisheries Research Institute at Fisheries Harbour, Cochin, within an area of 250 m^2, for rearing grouper fingerlings to broodstock; for carrying out experiments on breeding, hatchery production of seeds and grow-out production, in 5-mt capacity FRP tanks using *in situ* biofilters and recirculating sea water systems.

Broodstock: Groupers are protogynous hermaphrodites, maturing first as a female and becoming a male later as age advances. According to Tan and Tan (1974), *Epinephelus tauvina* first matures as female at 45-50 cm and 2.5-3.0 kg; beyond 72 cm (10kg) all are males, with transitional gonads occurring in specimens of size 62-70 cm. Males are larger in size, fewer in number and occur in the deeper seas. Brood fish can either be caught from the wild and made to spawn after conditioning them in captivity or can be reared from fingerlings under captive conditions. Lack of improved methods of catching the breeders from the deeper grounds, stress to the animals caused by sudden change in environment are the major constraints experienced in capturing spawners from the wild and maintaining them. In view of these problems, it is desirable to rear the fish from fingerlings and then hormonally transform them into males for effective spawning under captivity. Chen *et al* (1977) and Chao and Chow (1990) reported that male hormone (methyl testosterone) administered orally or through pellet implantation could transform mature females as well as immature fishes into functional males. Sex reversal and spawning (both induced as well as spontaneous) of many species have been achieved in many of the South East Asian countries and also in Kuwait. (Chao and Lim 1991; Chen *et al.* 1977; Hussain and Higuchi 1980; James *et al.* 1997).

In India, the Central Marine Fisheries Research Institute has accomplished major breakthroughs:

1. in developing an onshore, indoor, sea water recirculating facility for holding and growing the groupers
2. in rearing *E. tauvina* from fingerling stage to maturity and spawning in captivity
3. sex reversal through hormonal intervention
4. successful spontaneous spawning, 74-92% fertilization and larval rearing up to day 13, in the onshore, indoor facility

In the experiments at the Mariculture Laboratory at Fisheries Harbour, Cochin, the fingerlings of *E. tauvina* collected from the wild were stocked in March 1996 in 5-mt capacity FRP tanks in recirculating sea water system under controlled conditions of salinity, temperature, pH, and dissolved oxygen (Mathew *et al.,* in press ***b.***). The salinity in the tanks was maintained at 30 ± 2 ppt, temperature at 26^{o} and 29 ^{o}C and pH at 7-8 round the year. Fishes were fed trash fish collected from the trawler landing at the rate of 10 % of their body weight, in the initial stages. After one year, they were fed only 4-5% of their body weight. From the third year onwards, the regular food was supplemented with enriched diets containing Vitamin E and HUFA. The fishes were periodically examined for determining gonad condition through biopsy. Fingerlings of *E. malabaricus* obtained along with *E. tauvina* were also reared in the same facility but in separate tanks following the same procedure adopted for *E. tauvina*.

Sex inversion: The male hormone (17∝ methyl testosterone) was administered to a few selected females of *E. tauvina* and *E. malabaricus* of about 28 months age orally through the food. The hormone was made into pellets using gum acacia and cholesterol. The pellets were inserted into the trash fish and fed at the rate 2-3 mg /kg body weight. These fishes were periodically examined for the presence of milt. On administration of the hormone for a period of two months, the females of *E. tauvina* got transformed into spermiating males but those of *E. malabaricus* did not. Infact the hormone administration was continued in the *E. malabaricus* for 11 months till March 2000 but the sex reversal did not take place.

Spontaneous spawning and egg quality: The hormone treated male and a fully mature female of *E. tauvina* placed in one of the 5 mt tanks, under similar water quality and environmental conditions as in the other broodstock tanks, spawned spontaneously between 1600 and 2000 hrs, releasing 0.25 million eggs on 29th October 1998 for the first time. Spawning continued up to the fourth day. Diameter of fertilized, buoyant eggs ranged from 880 microns to 920 microns, with a single large oil globule measuring 190 microns. The same fishes spawned again during December1998, May, June, July, October, November and December 1999. The number of eggs released in each spawning varied from 0.25 to 2 million. Fertilization rate ranged from 74 to 92%. Percentage of buoyant eggs also varied from 75 to 90 % (Fig. 2). In the case of *E. malabaricus* maturation to ripeness did not take place.

Collection of eggs and incubation: The eggs were collected from the spawning tanks using a net of 300μ in the morning after the spawning, either by the overflow method or by siphoning out the eggs. The collected eggs were washed clean using seawater to remove any debris adhering to them, and then placed in graduated glass cylinders for estimation. The unfertilized eggs and the bad eggs were removed from the bottom by siphoning out. Fertilized eggs were transferred to the incubation tanks in seawater of salinity of 30-32 ppt at a density of 150-200 eggs/litre. A mild aeration was supplied to the incubation tanks. The eggs hatched out 22-23 hours after spawning. The temperature at hatching varied between 26 and 28 °C. After hatching is over, dead eggs as well as the eggshells were removed by siphoning. Hatching rate up to 65% was obtained.

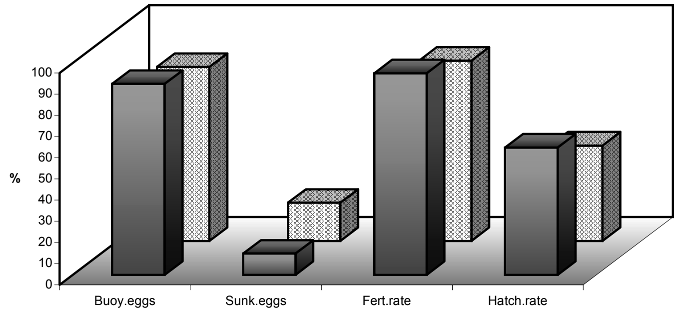


Figure 2. Egg Quality, Fertilization and Hatching rate in *E. tauvina*

Hatching and larvae: The newly hatched larvae measured 1.68mm to1.74mm in total length, were transparent and possessed a large yolk sac, unpigmented eyes and the oil globule lying at the posterior end of the yolk sac. The larvae exhibited vertical movements with head upwards (Mathew *et al.,* in press b). Two day old larva measured 2.64 mm in total length. After 56 hours, pectoral fins developed, jaw buds started developing, gut increased in length, oil globule and yolk sac diminished in size and the larvae measured 2.68mm. At about 65 to 68 hours after hatching, the larval mouth opened, jaws started moving, gut started contractions, anus opened and eyes became pigmented. Yolk was almost absorbed and the oil globule reduced to negligible size. At this stage a number of melanophores developed along the dorsal and ventral portion of the alimentary canal.

Strict water quality management and maintenance in the hatchery system is highly essential in larval rearing. The CMFRI also has accomplished large-scale production of live food organisms. (Micro-algae, Rotifer, *Artemia, Moina* and various species of copepods) which form the major food for rearing the larvae. There is however, need for developing technology for continuous production of live feed.

Larval rearing: Upon hatching, the larvae were stocked in indoor 300 to 500 litre tanks. Seawater used in the larval rearing tanks was pre- treated through UV and biofilter. The tanks were provided with a central standpipe and provision for water drainage from the top. Seawater used in the larval rearing tanks was of salinity 30 ppt.

Larvae were stocked into the rearing tanks at a rate of 30 larvae/litre. *Nannochloropsis* sp was introduced into the larval rearing tanks and algal cell density was maintained at 300×10^3 cell/ml. Temperature, pH and dissolved oxygen were monitored in the larval rearing tanks every two hours. From the second day onwards, the rotifers were introduced into larval rearing tanks as live feed, a 10% water exchange was made in the larval rearing tanks from the second day onwards. Larvae of *E. tauvina* were reared at the Field Mariculture Laboratory of the CMFRI, at Cochin, up to day 13, till the larvae measured 4mm and developed pectoral spines.

Diseases: Disease is one of the major causes of mortality in the grouper grow-out system, broodstock and in the nursery rearing stages. Bacterial and parasitic infestations cause heavy mortality in juveniles as well as adults. Prior to stocking, the grouper fingerlings were given a bath for 30 minutes in 25-40 ppm formalin and subsequently treated in nitrofurazone for 2 hours at a concentration of 10 ppm. The parasites afflicting groupers in the aquaculture system were mainly: (1) the protozoan, *Cryptocaryon* which cause "ich" or white spot. These got attached to the skin and scales first, some get attached to the gill filaments, disturb the normal functioning of the gill, the fishes swim to the surface and gulp air and later die. (2) *Trichodina*, this protozoan attacks the gill, produces a lot of mucus, and mostly affects the fingerlings. Non-protozoan parasites which attack mostly the juveniles and fingerlings of groupers include the monogenic trematodes and crustacean parasites. Stress leading to poor resistance caused disease affliction in these fishes. Nitrofurazone (9.3%) was used at 10 ppm for stress related bacterial infection whenever this was encountered in the grow-out culture system as also to the broodfish at our Mariculture system at CMFRI.

Experiments on growout production: Fingerlings are caught from the wild by dragnets and traps. Recent surveys conducted by the CMFRI have enabled the identification of a few grounds in the inshore waters and the peak season for collection. Young ones of *E. tauvina* and *E.malabaricus* occur in the eel grass beds at 10m depth during northeast monsoon period in the nearshore region off Tuticorin. Grouper seeds in the size range 60 to 200mm are collected by the fishermen operating mini shore seine and transported for stocking in coastal ponds at Tuticorin, outdoor cement tanks at Mandapam, and also in the silpaulin-lined ponds and the indoor FRP tanks at Cochin. Stocking rate was not uniform in the different culture systems.

The results obtained from the recirculating sea water system at the Field Mariculture Laboratory at the Cochin Fisheries Harbour was quite encouraging (Mathew *et al* in press a). The grouper fingerlings were stocked at the rate of 4 nos/m^2 and fed trash fish twice a day to a total of 10 % of their body weight. Artificial hiding places inside the tanks were provided where the fish remained sluggish throughout the day, moving out only at the time of feeding. The average weight attained after seven months of culture in this system with water quality parameters remaining constant throughout the period and feeding to satiation point, was 775gm. This growth is comparable to that reported by Surtida (1999) in the open sea net cage culture system at SEAFDEC and better than that reported in the tank culture system, with aerated running sea water in Saudi Arabia (James *et al* 1997). In the silpaulin -lined earthen ponds, fingerlings of initial weight of 10g fed trash fish and live Tilapia as feed, gave a growth of 1696g in one year period. Grouper fingerlings stocked in the 100mt outdoor tank with seawater flowthrough system and in the earthen ponds with tidal influence and fed chopped sardines and live tilapias, gave average growth of 40.8 g per month (CMFRI 1999).

Constraints in grouper aquaculture:

- Lack of hatchery technology
- Poor knowledge on the biology of different cultivable species of groupers
- Poor knowledge on probable live feed for larval rearing at different stages from the time of mouth opening

Recommendations

- Conduct a survey of areas where open sea net cage culture could be carried out taking into account the oceanographic, meteorological and social conditions of the region and development of growout facilities in the open sea along the different regions
- Develop onshore broodstock development facilities along Gujarat, Kerala, Tamilnadu and the Andaman regions
- Develop technology of sex reversal through hormonal intervention or manipulation by maintaining pairs of fishes of one year age and above
- Understand the live feed requirements for larval rearing from the time of mouth opening
- Intensifying research on the development of a reliable hatchery production technology for cultivable species of groupers
- Develop enriched diets for broodstock, larvae as well as the juveniles
- Intensify research on the diseases in culture system
- Impart training of at least one year duration to scientists on all the above aspects so as to develop a multidisciplinary national team on grouper aquaculture.

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