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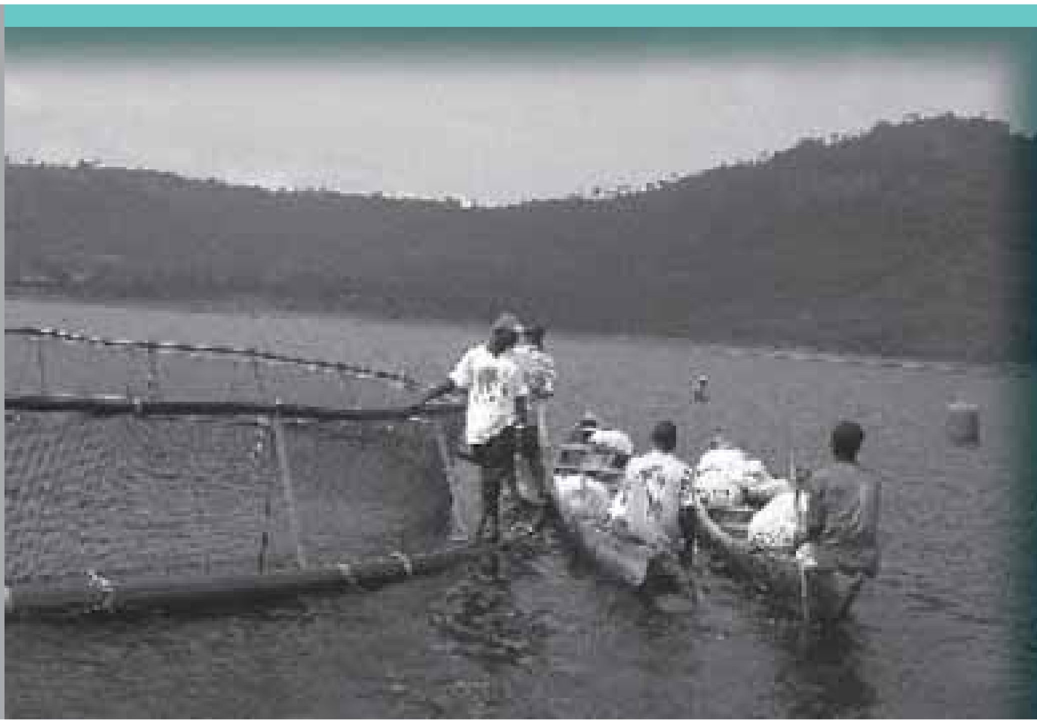
FAO Regional Technical Expert Workshop on

Cage Culture in Africa

20–23 October 2004
Entebbe, Uganda



Cover photo:
Cage culture of Nile tilapia *Oreochromis niloticus* on Lake Volta, Ghana.
Courtesy of John F. Moehl.

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FAO Regional Technical Expert Workshop on

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Preparation of this document

This document contains the proceedings, including eight papers presented, working group reports and recommendations, of the FAO Regional Technical Expert Workshop on Cage Culture in Africa, held in Entebbe, Uganda, from 20 to 23 October 2004.

The workshop was organized by the Inland Water Resources and Aquaculture Service (FIRI) of the Food and Agriculture Organization of the United Nations (FAO) and the Lake Victoria Fisheries Organization (LVFO). It was hosted by the Uganda Department of Fisheries. The workshop was supported with financial assistance from the United States Agency for International Development (USAID).

Valuable inputs during the preparation and conduct of the workshop were received from J. Hambrey who served as a resource person funded by the UK Department for International Development (DFID). Copy-editing and final layout were done by M. Nolting, P. Balzer and C. Veiga.

The final inputs and revisions were provided by the editors M. Halwart and J.F. Moehl. The publishing and distribution of the document were undertaken by FAO, Rome.

Abstract

This document contains the proceedings of the FAO Regional Technical Expert Workshop on Cage Culture in Africa, held in Entebbe, Uganda, from 20–23 October 2004. The workshop was attended by 71 participants including regional participants from public and private sector, resource persons from Italy, Norway, Thailand, the United Kingdom of Great Britain and Nothern Ireland and Zimbabwe, observers, the FAO Technical Secretariat and support staff. The workshop was unanimous in concluding that cage aquaculture represents an important development opportunity for many African countries, but will require an effective policy framework to ensure that structural constraints to development are overcome, and that development is equitable and sustainable. Successful development of cage aquaculture will depend on many factors. The challenge for both government and private sector is to work together to address these issues comprehensively – at farm, local, national and regional levels.

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FAO Regional Technical Expert Workshop on Cage Culture in Africa. Entebbe, Uganda, 20-23 October 2004.
FAO Fisheries Proceedings. No. 6. Rome, FAO. 2006. 113p.

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Foreword

In 2004 the Food and Agriculture Organization of the United Nations (FAO) and the Lake Victoria Fisheries Organization, in collaboration with the Uganda Department of Fisheries and support from the United States Agency for International Development (USAID) and the United Kingdom Department for International Development (DFID), convened an expert workshop on cage culture in Africa. This activity was given a high priority considering the rapidly growing interest in cage culture systems, largely due to increasing knowledge of the technical successes attributed to cage culture on Lake Kariba.

In view of noteworthy concerns by a variety of stakeholders concerning the potential negative impacts of cage systems, the original intent of the workshop was to develop guidelines for undertaking cage culture on African lakes and reservoirs. It was initially hoped the workshop would be able to identify a set of critical parameters which could be evaluated during the planning stages of cage projects to assess potential positive and negative impacts.

Subsequent chapters of this document submit the workshop recommendations, proceedings and selected papers presented. However, an explicit set of guiding parameters is still to be elaborated. These tools are even more necessary today then when the workshop was held given the recent expansion of cage culture on Lakes Victoria, Malawi and Volta as well as on a number of minor waters.

To address this need, funds permitting, FAO may assist in the elaboration of a pilot cage management plan on a major African lake or reservoir. This plan would include means for estimating maximum and optimum levels of cage production; these tied to natural fertility and prevailing limnology. The plan would describe suitable cage sites along with pre- and post-production monitoring programmes. The plan would also incorporate socio-economic aspects of cage development including such pivotal issues as access, ownership, theft and profitability.

Once completed, such pilot plan could be contrasted with cage scenarios on other water bodies where these systems are operating. This contrasting process is intended to identify crosscutting elements which could apply to assessing the pros and cons of introducing cage systems into any surface waters.

It is also anticipated that south/south cooperation mechanisms will be used to facilitate information exchange, provide training opportunities, and identify those cage management and monitoring techniques from other parts of the world which could be applied to the African region.

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Executive summary

The FAO Regional Technical Expert Workshop on Cage Culture in Africa was held in Entebbe, Uganda, from 20 to 23 October 2004. The workshop was attended by 71 participants including regional participants from public and private sector, resource persons from Italy, Norway, Thailand, United Kingdom of Great Britain and Northern Ireland, and Zimbabwe, observers, the FAO Technical Secretariat and support staff.

The objectives of the workshop were to identify the key issues requiring priority action for sustainable cage culture development in the region and to elaborate a framework of good management practices based on practical cage-growing experiences from Africa and other regions of the world in order to promote rational development of cage culture in the Africa region. The workshop was unanimous in concluding that cage aquaculture represents an important development opportunity for many African countries, but will require an effective policy framework to ensure that structural constraints to development are overcome, and that development is equitable and sustainable.

Cage aquaculture depends on the natural resources of water, seed and feed. Many of these are shared resources – locally, nationally and in some cases regionally. A better understanding is needed, and appropriate mechanisms, to ensure that these resources are developed and managed equitably and sustainably.

Cage culture is risky, and requires significant skill and adaptive learning at farm level. This makes entry for the poor difficult, and they will require much support if they are to succeed. In this regard, many lessons can be learned from attempts to promote pond aquaculture. Larger enterprises have the resources that allow them to make mistakes, learn, survive, and ultimately thrive. But unless they engage the local community through quality employment, supply enterprises, and possibly out-grower schemes, they are likely to encounter resistance and in some cases conflict. Fishers in particular may perceive their livelihoods to be threatened.

Seed and feed have been identified as major constraints to aquaculture development, and many examples of failed pond aquaculture can be attributed to feed or seed availability, quality and cost issues. Through their economies of scale and buying power, medium and large scale enterprises can play an important role in promoting and developing efficient feed and seed sub-sectors. This may in turn facilitate the development of smaller scale cage culture through the increased availability, higher quality, and lower cost of input supplies.

Cage design and construction is also a crucial issue. While much can be learned from other parts of the world, it is essential that cage design takes full account of both local conditions (wind, waves, predators) and also opportunities for the use of local materials.

Knowing the market, and exploiting comparative advantage, is fundamental to success. International markets offer enormous opportunities, but the costs of access can be high, especially for small-scale producers, and there are risks associated with unilateral trade restrictions and anti-dumping measures. Local markets offer good potential, especially for growers close to major urban centres, and for smaller producers more generally.

Facilitating successful entry into cage culture through finance and capacity building remains a complex and difficult area, and there have been many failed projects. There are some fundamental lessons however: finance and skills development should be closely linked; and finance must be appropriate to the nature of cage aquaculture. There are opportunities for innovative credit schemes run through non-governmental

organizations (NGOs) and the private sector, and also for private sector service provision. Existing government training and research institutions can also promote and increase their service provision to the private sector, and where appropriate engage in public-private demonstration and applied research projects.

Overrapid and overconcentrated aquaculture development can negatively impact the environment with a range of consequences for other resource users, and for farmers themselves, in terms of poor water quality, reduced growth and increased disease. Environmental Impact Assessment (EIA) requirements for larger farms can address these issues to a point. However, this approach is inadequate to deal with many small scale developments, impacts from other sectors, and longer term cumulative impacts. There needs to be more strategic environmental assessment and management for larger water bodies which takes account of all the economic activities affecting the aquatic environment, and the capacity of the environment to assimilate wastes. To do this accurately is costly, but rough estimates are relatively straightforward, and when coupled with effective monitoring and response procedures, can be used effectively in the short to medium term.

Successful development of cage aquaculture will depend on many factors. The challenge for both government and private sector is to work together to address these issues comprehensively – at farm, local, national and regional levels.

1. Background

Cage culture is an established and profitable aquaculture system in many countries. Cage culture is also a relatively complex culture system from technological, biological, ecological, economic and social perspectives. While the financial success of cage culture has been demonstrated in Europe, North America, Latin America and Asia, cage culture is still in its infancy in the Africa region. Cage rearing of fish was introduced in several African countries in the 1970s. However, only few of these early attempts proved to be sustainable. Recurrent barriers to sustainability included, among others: disease problems with cultured organisms, high investment costs combined with difficult access to credit and/or necessary materials for cage production, unavailability of cost-effective high quality fish feeds; concerns regarding the use of cages in areas considered as public domain and challenges in marketing of cage-reared products. In extreme cases, cage operators have had their cages destroyed and have been incarcerated for undertaking "illegal ventures".

Although there were some intermittent efforts to introduce small-scale cage culture activities, the first major private sector-led operations were established in the lagoons of Côte d'Ivoire in the 1980s and 1990s. These were able to demonstrate the technical and economic feasibility of an otherwise problematic culture system. They were followed by a large capital venture in cage culture on Lake Kariba in the late 1990s. Over the past several years, these reportedly lucrative enterprises have flourished and became targets for would-be investors. There are now serious candidates for medium- and large-scale cage culture operations on Lakes Victoria, Malawi and Volta as well as interest in expanded production on Lake Kariba and in Côte d'Ivoire. Additionally, Burkina Faso, Cameroon, Madagascar, Mozambique and Nigeria have expressed varying degrees of interest in initiating cage culture. In several of these countries, cage production on lakes and mainstream reservoirs can be complemented by significant supplemental small-scale production coming from cages on small waterbodies.

However, as interest in cage culture grows, the earlier impediments to cage rearing of fish remain and, in some cases, may well have exacerbated. The technology remains problematic in many areas. Input difficulties in terms of feed, seed, materials and capital are affecting investment in all aquaculture enterprises as are challenges in finding suitable markets. Cage culture is also subject to real and perceived issues regarding impact on capture fisheries and the environment, effects on tourism, access and ownership of aquatic habitats as well as influences on riparian societies. In the aggregate, these concerns combine to form a formidable set of potential hurdles if one is to establish profitable and environmentally friendly cage production. Problems in addressing these concerns are amplified by significant differences between various biophysical and socio-economic settings across the Africa region combined with a frequent lack of prerequisite aquaculture legislation and regulation, or even guides for good management or best practices. This situation in some cases has contributed to the current state of affairs where polarization is developing between potential investors/operators and those who are responsible for environmental protection and socially conscientious development.

Cage culture is now a serious option for the aquaculture investor in Africa. Cage culture has the potential of producing large quantities of fish for export and domestic markets. There is a growing number of investors who are realizing these opportunities, but who are discouraged if not hampered by the lack of necessary guidance as to best practices. These businesspersons are confronted by their counterparts in the public sector and civil society who are also concerned about the lack of necessary procedures, leading to uncertainties as to when and where to support cage development. The two groups are growing both in numbers and concern. In response to this urgent and growing need, FAO convened this workshop to identify the key issues requiring priority action for sustainable cage culture development in the region and to elaborate a framework of good management practices in order to help countries to promote rational development of cage culture in the Africa region.

2. Technical workshop

2.1 OBJECTIVE

At the request of several member countries, FAO initiated this regional workshop in 2004 for participating countries to profit from cage culture experiences elsewhere in the world, to develop an initial framework to orient cage development in Africa and to identify areas where additional effort is required.

The objective of the workshop was to promote rational development of cage culture in the Africa region by elaborating a framework of good management practices based on practical cage-growing experiences from Africa and other regions of the world. This framework was to be complemented by a list of subjects requiring priority action in the short-term to facilitate their evolution into workable guidelines that can be applied to cage culture by all member countries in the region.

The workshop was organized by FAO and the Lake Victoria Fisheries Organization in collaboration with the Uganda Department of Fisheries and support from the United States Agency for International Development (USAID) and the UK Department for International Development (DFID). It took place in Uganda where fish production is a principal contributor to the national economy and interest in cage culture is rapidly increasing.

2.2 STRUCTURE AND PROCESS

The workshop started with a presentation on the particular challenges that this sub-sector faces, followed by country and regional experiences from outside and within the region including cage operators or potential operators from the Africa region describing their operations, existing or planned, and the difficulties they encountered in coming to production and continued challenges they face.

Following presentations, participants organized themselves into three working groups to prepare recommendations according to the guidelines for working groups (Appendix 3) and concerning:

- environmental impact including components of a pre-implementation assessment and monitoring during operations (Working Group 1);
- biological impact including assessing and monitoring impact on capture fisheries, control of fish health and uses of non-indigenous species (Working Group 2);
- socio-economic impact including assessing and monitoring social impact and economic profitability (Working Group 3).

These recommendations were then reviewed in plenary and adopted as workshop recommendations. Participating countries included Côte d'Ivoire, Ghana, Kenya, Malawi, Mozambique, Nigeria, the United Republic of Tanzania, Uganda, Zambia and Zimbabwe.

3. Working groups

The following is a narrative synthesis of the major points raised in the three working groups, as recorded in the tables (see Annexes 3.1, 3.2 and 3.3). The issues identified by each group are briefly reviewed, including lessons learned from experience in Africa and elsewhere. Although there is necessarily some overlap between the findings of the three groups, the text has been rationalised to minimise duplication as far as possible.

3.1 BIOLOGICAL AND TECHNICAL ISSUES

Interaction with capture fisheries, escapes and disease

There are positive and negative interactions between aquaculture and capture fisheries. Waste food can attract fish and increase fishing activities around cages with positive economic impact, but can also generate conflicts. Both positive and negative biodiversity impacts may be associated with sediments below cages, and wider ecosystem effects on fisheries may arise as a result of increased nutrient status at very high levels of production or in small enclosed water bodies. Chemicals can have direct negative impacts on fisheries. Escapes of farmed stock can have positive or negative impacts, and where these are alien species there may be significant irreversible long term effects.

Disease is a major risk for cage aquaculture, and fish health management is an essential part of business planning and good husbandry. Disease may be exchanged between wild and farmed stocks.

Feed and seed

Feed and seed are repeatedly identified as key constraints to aquaculture development. Without seed there is no aquaculture, and without high quality seed and feed there is poor growth. Seed must be available year round, of good quality, and at an acceptable price. Some countries in the region have limited supplies of appropriate feed ingredients, and transport costs can be high. Feed costs and pollution can be greatly reduced through good formulation and feed management practices.

Production systems

Cage and systems design will depend on the species farmed, the production system used, the site and scale of operation. Site selection and design make all the difference to economic viability.

Cage design must take full account of operational needs of stocking, sampling, monitoring, removal of dead fish and harvesting, as well as the regular or occasional threats from predators and severe weather.

A farm however comprises far more than just cages. Boats, vehicles and onshore infrastructure are required to support the larger scale enterprises, and comprehensive maintenance of all components is critical to success.

3.2 ENVIRONMENTAL ISSUES

The wider context

Aquaculture both affects and is affected by the environment. Aquaculture must therefore be considered and assessed in the context of all the other activities that affect the aquatic environment and associated systems. Fish farmers need to develop national associations to represent their interests within this wider context and also to act as a conduit for the exchange of information.

Practices which optimise production efficiency – especially the use of feeds – can also reduce environmental impacts. Exchange of knowledge about feed quality and practice (through farmer networks for example) is therefore essential to promote better environmental practice.

Environmental assessment and aquaculture management plans

Individual fish cages have limited and temporary effects on the local environment, but as cage aquaculture develops there is a cumulative and eventually a wider impact on the environment. There is therefore a need for a regulatory framework, based on environmental standards and an assessment of environmental impacts.

The capacity of the environment to assimilate nutrients varies greatly according to local conditions of depth, hydrography, water exchange and sediment type. Information on environmental conditions and agreement on environmental standards are required as a baseline for planning, environmental assessment and decision making.

Plans should be developed for cage aquaculture which identify suitable sites and zones for both large scale and small scale cage aquaculture development, taking account of socio-economic as well as environmental needs. The capacity of each zone should then be estimated as far as possible, and monitoring of cage sites and the surrounding environment established to determine any environmental changes and adjust plans and operations as required. The costs of environmental monitoring and management should be recovered through licenses or site rental.

In larger water bodies strategic environmental assessment should be undertaken to establish the basis for planning cage aquaculture. In shared water bodies it will be necessary to collaborate with neighbouring states to conduct strategic EIA and develop and agree joint higher level management plans.

Permits

Experience throughout the world has shown that some form of permitting or licensing system is essential if cage aquaculture is to be effectively monitored and managed.

In many countries the existing system is time consuming and bureaucratic, with many agencies involved, and without any one agency with overall responsibility for processing permits. Licensing periods are often too short to encourage adequate levels of investment. Standards are unclear and inconsistent. This contrasts sharply with the situation on land.

Conditions need to take account of the needs of cage culture with respect to the particular conditions associated with the "farm zone" within which the cages are to be established and the need to move cages to allow for the fallowing of sites.

License fees and/or conditions can be used as a mechanism to contribute to ongoing environmental assessment, monitoring and management.

Establishing effective and integrated regulatory frameworks

There is a lack of institutional arrangements and coordination among the public sector institutions to establish the regulations necessary to respond to cage aquaculture development.

Aquaculture, and more specifically cage culture has been largely outside the remit and operations controlled by institutions responsible for inland and marine water resources and management. As a result, aquaculture does not feature in many inland and coastal water resource management plans. Even where included in plans implementation is often weak.

Feeds and feeding

Waste food and metabolic wastes from cage aquaculture can be an important source of organic matter and nutrient enrichment of the environment. While the impacts may be positive at low to medium levels of enrichment, they can be harmful to aquaculture itself and other interests at higher levels. Improved feed formulation and feeding practices can significantly reduce waste loadings, while at the same time leading to improved economic performance. Availability of high quality feed is, furthermore, a significant constraint to economically viable aquaculture development.

Understanding of feeding behaviour and the development of good feeding practices is essential to minimise waste and maximise growth. Particular mixes of species in polyculture may result in more efficient feed utilisation.

Farm made feeds and recycling of local resources, should be encouraged where this does not compromise economic viability or contribute to excessive pollution. For larger scale operations it is usually better to use quality extruded feeds to safeguard the environment and improve feed conversion ratios (FCRs). Traceability standards applied to feeds can encourage high standards.

At a large scale, aquaculture may compete for feed ingredients with other livestock and with direct human consumption. This complex issue requires careful assessment and the development of appropriate government policy.

Disease prevention and management

Disease represents a major threat to the viability of aquaculture and has been the cause of its decline in many situations. Good seed quality, improved environmental conditions, improved nutrition, better handling and controlled movement of live stock can all reduce disease. Practical experience and traditional knowledge can also contribute to fish health.

Excessive use of chemicals has often been associated with aquaculture, and can be the cause of threats to product quality and human health. The need for chemical use should be reduced to the minimum by using effective disease prevention measures. When chemical use is absolutely necessary, only approved chemicals should be used in strict compliance with best practice or on professional advice.

Non-indigenous species

There are risks to aquatic biodiversity from the introduction of exotic species – between continents, regions, countries and watersheds. Indigenous species should therefore be used for cage aquaculture. Although there is substantial guidance on this issue, agreed protocols are still lacking in many circumstances. Government can play a significant role by developing appropriate policy and protocols, supporting breeding programs for indigenous species, and encouraging the culture of indigenous species wherever possible. Where introductions are considered desirable the risks should be fully assessed.

The image of aquaculture

Adversaries of cage aquaculture have been successful in creating a negative impression of the industry globally. This has been enhanced by the dearth of accessible and objective information, especially at local level, and the reluctance of operators to divulge information for commercial and bio-security reasons.

Farmer associations and individual operators need to engage more pro-actively in addressing the issues, and in education and communication of the issues. Associations can build multi-disciplinary groups to respond to occasional adverse publicity and public concerns. Image building with communities, policy makers, and potential buyers should be a continuous process.

Skills

Skilled people within regulatory and scientific bodies and cage farming operations are essential to support development of a sustainable industry in Africa. To underpin this we also need to build capacity amongst institutions to support skills development.

3.3 SOCIO-ECONOMIC ISSUES

Financial assessment and business planning

Cage aquaculture is risky. Before any individual, regional or national project is undertaken to develop cage aquaculture, there is a need to undertake a thorough rational appraisal of financial viability and risk, and compare cage aquaculture with alternative activities. This is a relatively straightforward exercise that is rarely undertaken, and even more rarely conducted well.

Once the decision is made to undertake aquaculture, there should be an effective business planning process to ensure that the development is undertaken as well as possible, taking full account of local social, economic and financial issues, and input supply and market trends. The objective of good business planning is to minimise risks, and create a competitive and sustainable business enterprise. This should be undertaken even for the smallest of enterprises, and capacity building is required to encourage thorough assessment and business planning.

There is much to be learned from previous experience with pond aquaculture, especially as regards the feed and seed supply and markets. But it will also be necessary to make a thorough appraisal of cage design and construction in relation to local conditions (in particular wind, waves, currents, predators). Social issues such as conflict and theft will also need to be addressed, as will the risks from disease or water quality and the need for appropriate management. The necessary skills and manpower may take time to deploy and may delay full production and efficient use of resources. Incentives need to be in place to promote worker commitment and dedication.

The minimum viable scale of operation needs to be assessed as well as a range of site specific technical issues including stocking and harvesting strategies. In practice, pilot scale production to identify practical local problems and learn from experience is usually desirable, but the exercise should be treated as a commercial operation if commercial learning is to take place.

Marketing strategy will be a key issue and is covered in more detail below.

Input costs, quality and supply

Cage design and construction are critical to success. The drive for low cost must be balanced by the need for reliability and high water quality in sometimes demanding circumstances. Sometimes it will be better to use local materials; sometimes it may be necessary to import. Sometimes it may be cost effective to adapt foreign design for local conditions and/or using local materials.

As noted elsewhere, seed quality, availability and cost is a common constraint to cage culture development. Wild seed can play an important part in "kick-starting" growout, but hatchery produced seed must be the medium to long term objective. Unfortunately government involvement in seed production has often failed. We need to explore new forms of public-private partnership to ensure that commercial discipline is brought to the "seeding" and support of hatcheries in the early stages of development. Small and local hatchery/nursery operations can underpin rural cage aquaculture, and the many existing ponds may be a potential resource for dedicated small scale hatchery operations. We also need to explore mechanisms to guarantee high genetic quality of seed.

Feed quality, availability and cost is also a common constraint. Many cage systems have begun and developed through the exploitation of local low value fish and other feed ingredients, but as with seed, commercial dry pellet production should be the medium to long term objective. Local production of moist or dry pellets using relatively simple equipment may serve as an important intermediary step and should be encouraged.

There are some important social and nutrition issues that need to be addressed. Demand for feed materials in livestock production of any kind can drive up prices with potential negative impacts on the poor, and where this is high quality protein these effects could be significant.

Distribution and markets

Market access and distribution systems often develop spontaneously where there is production in one area and demand in another, but this is not always so - for reasons of infrastructure, culture, and tradition. Large producers can overcome this problem by becoming involved in distribution themselves, but this may be dangerous for smaller enterprises. Government may assist by identifying specific bottlenecks or opportunities and focusing resources temporarily to overcome the blockage. Mobile phone commodity price indexes are increasingly available and useful, and have the potential to revolutionise market intelligence for producers.

Export markets represent an important opportunity, but caution is required. Experience elsewhere in the world demonstrates that international markets may be unreliable. Standards or antidumping measures can be introduced at short notice with significant negative effects on the industry. Furthermore the apparent price premium of international markets may be outweighed by costs of market access especially for small and medium scale enterprises. National markets have significant potential, especially close to growing urban centres.

Although cultural taboos relating to food fish are in decline, a range of factors can affect domestic demand. Preferences for 'capture fish' can exist, based on size, taste, species - and these must either be supplied with an appropriate product or perceptions changed and demand increased through information and promotional activities.

Quality is increasingly important in all markets, but production standards must be tailored to the target market.

Positive and negative social impacts may be generated through supply to local markets. Increased supply may result in lower prices, which will benefit local communities, increase the acceptability of cage culture, and reduce the potential for conflict. On the other hand lower prices may negatively impact fishermen and increase conflict, unless fishermen themselves become involved.

Rights and access

There are examples from throughout the world on conflicts between fish farmers and fishermen. This problem is exacerbated by the ambiguity of ownership and common access to many water bodies, and even more so for international water bodies. Suspicion of Government by many fishing communities can increase tensions, especially in relation to outside investment.

Experience from elsewhere suggests that cage culture will be blamed for any and all future lake or fishery problems. Fish farmers need to be pre-emptive: engage local communities and ensure they benefit and identify upcoming issues and deal with them before it is too late. Zoning can reduce conflict, but can also reduce opportunity for smaller scale producers and needs to be undertaken with full participation and great sensitivity.

Promoting entry – finance and capacity building

Government and development project backed aquaculture credit schemes have often failed, mainly through a lack of understanding of the nature of aquaculture and its associated risks. There are also questions about the sustainability of credit driven development. Much can be learned from an examination of efforts to promote development of pond aquaculture and small scale agriculture. Targeting extension efforts to high potential clients works better than blanket or group approaches, and linked credit and extension, training and support services is essential for any small scale development. Any capacity building or assistance should be premised on an understanding that cage culture is a serious and risky business, and in most cases not suitable as a subsistence or part time activity. Fortunately, farmer to farmer information exchange can be relatively high with cage culture due to clustered nature of small scale producers and opportunities for the rapid evaluation of the effects of management.

Government policy can have a significant impact on the provision of private finance. There are examples from Africa and elsewhere in the world of highly effective local and micro-credit schemes delivered through or by local NGOs and private finance institutions. These can be tailored to local needs and conditions and accompanied by effective extension support. Needless to say, high interest rates can cripple a small enterprise, especially during the learning phase.

Any form of credit at any scale of development should be dependent upon a through financial appraisal and business plan. Potential small-scale producers may need assistance to develop these plans as noted in the section on business planning above. Research stations can assist the sector, especially through assistance and applied research related to the many local and practical difficulties often encountered in the early stages of developing a viable aquaculture enterprise

Structural issues and poverty alleviation

Aquaculture often fails to take off because of structural problems, including mismatches of demand for and supply of inputs; lack of scale for efficient production and market access; and lack of infrastructure to allow for fresh market access. Private-public sector partnerships and cooperation can be effective in addressing these issues.

We have already noted the difficulties of engaging the poorest people in aquaculture as a part time or subsistence activity. However, successful commercial enterprises generate substantial direct and indirect employment in service and supply industries – in feed and seed supply, net making, construction materials, processing etc. Large investors may also be persuaded to behave in ways that ensure local benefits,.e.g. through conditions requiring a net increase in local fish supplies by importing fish meal; fair pay and working conditions; training and skills development. There are examples of successful out-grower schemes, run by both feed companies and large production companies, in many parts of the world.

4. Recommendations

The recommendations presented below are drawn from the working group discussions and the final discussion session of the workshop. Where appropriate, the major recommendations are presented under two sub headings: recommended actions at the farm level ("good practice"); and recommended actions at the sector or regulatory level. These latter may be regulatory, support or research actions.

4.1 BIOLOGICAL AND TECHNICAL ISSUES

Interaction with capture fisheries, escapes and disease

Good practice

- The interaction with capture fisheries can be addressed primarily through responsible and skilled site selection, feed management and chemical use.
- Monitoring systems should be in place where there is significant cage aquaculture activity.
- Avoid use of species not authorised by authorities. Use indigenous species where possible. If non-indigenous species are used sterilize them if possible. Prevent fish escapes through physical barriers and good management.
- Good disease management should include at minimum:
  - Stock healthy fish, and keep them healthy through proper management
  - Minimal and informed use of chemicals, professionally regulated where feasible
  - Use oral administration techniques where ever possible

Sector management and regulation

- Develop regulatory framework to address the issue of non-indigenous species.
- Develop regulatory framework for the use of chemicals, and perhaps also feed.
- Develop comprehensive strategy and support services for disease prevention and management.
- Estimation of environmental capacity and the identification of cage culture zones may be desirable if the scale of development is likely to be significant.
- Further research on the impacts of cages on capture fisheries, chemical usage and effects of alien species.

Feed and seed

Good practice

- Develop/source a good quality extruded or cooked feed – produced locally if possible.
- Develop efficient feed application regimes.
- Use quality seed purchased from proven suppliers.
- Avoid inbreeding.
- Use government approved species.
- Stock feed trained fingerlings of uniform size.

Sector support, management and regulation

- Encourage further development of animal feeds production.
- Encourage farmers to grow animal feed crops.
- Encourage research on high quality hatchery seed production.
- Exchange technology and information.

Production systems

Good practice

- Cage sites should be accessible to infrastructure, supplies and market, but should as far as possible minimise interactions with wildlife, humans and pollution.
- Cage and system design should be adapted according to species, production type, site and market, and should be undertaken professionally where possible. Cage design should maximise fish welfare, and minimise the need for fish handling.
- Passive grading techniques should be used where possible.

Sector management and regulation

- Encourage pooling of support infrastructure and resources for small and medium scale systems.
- Provide technical support services to assist with design.

4.2 ENVIRONMENTAL ISSUES

The wider context

- Environmental concerns about cage culture should be considered within the context of overall environmental conditions in a water body.
- Cage farmers and businesses should work with communities and regulators to improve environmental conditions in water bodies, caused by deforestation, agricultural pollution and erosion.

Environmental assessment and aquaculture management plans

- Governments should establish environmental standards for water bodies and consistent and clear criteria for environmental assessment of cage culture to benchmark and make development decisions.
- Capacity of large African lakes should be assessed, and strategic management plans developed for cage aquaculture. Donor and technical agencies should assist governments in such assessments if required.
- Share experiences on environmental standards, assessments and management plans for cage culture, such as through electronic newsletters and other publications.
- Build capacity and skills in environmental assessment, carrying capacity and planning for cage culture development. Request FAO to organize a regional course to assist in building skills.
- Develop a set of best management practices (BMPs), covering relevant environmental and quality standards, representative of cage culture systems in Africa, for widespread sharing. Organise national training on the BMPs supported by governments, regional organizations and NGO's.

Permits

- Prepare generic standards for permits/licensing which take full account of the problems identified above.
- Share knowledge on permitting licensing standards.
- Undertake research to investigate ways of generating revenue/taxing emissions from cage culture and other users to support environmental improvement.

Establishing effective and integrated regulatory frameworks

- Arrangements to control the use of international waters should be revised to accommodate issues related to industrial cage culture.
- In view of complexities involved in using international water bodies for cage culture the industry should be initiated in appropriate national waters especially those with least potential conflicts amongst users, in so far as possible.

- Water use policies need appropriate revisions to accommodate cage culture development.
- Awareness and understanding of cage culture needs to improve among administrators and decision makers.

Feeds and feeding

- Undertake research on feed formulation and feed management in cage aquaculture (e.g. use of local ingredients, formulation of feeds, farm-made feeds, environmentally friendly use).
- Share knowledge on feeds and research outcomes in the region.
- Governments should develop feed standards to provide guidance for feed formulation and avoid pollution problems in farmed fish.
- Prepare guidelines on feed formulation and feed management for wide dissemination in the region.
- Governments should provide incentives for procurement of appropriate feed equipment to reduce environmental impacts.
- Conduct research to carefully evaluate impacts on use of trash fish on ecosystems and human nutrition.

Disease prevention and management

- Governments should disseminate information on banned chemicals and responsible use of chemicals.
- Within the permit/licensing systems Governments should include reference to allowable chemicals.
- Governments should introduce regulations on health management and responsible movement of fish. Encourage cooperation among countries to develop common regulations/approaches.
- Encourage enforcement of existing hygiene standards.
- Research into development of cost-effective vaccines.

Non-indigenous species

- Research on development/improvement of indigenous species for aquaculture should be encouraged and monitored by regulatory agencies.
- Encourage partnerships between regulatory agencies and fish farming businesses in regulation and use of indigenous species.
- Develop regionally-agreed protocols for movement of indigenous species, introductions of exotic species and responsible transboundary movements of aquatic animals.

The image of aquaculture

- Farmer associations should be developed to address these and other wider issues.
- Cage culture operators and associations should deliberately create controlled public information awareness on their operation and products.

Skills

- Develop national and co-ordinated regional training programs, and exchange experiences, to support capacity building and skills development. This should be designed to promote and support the development of national, sub-regional and regional skills development programs.

4.3 SOCIO-ECONOMIC ISSUES

Financial assessment and business planning

- Individual farmers, irrespective of socio-economic status, should be encouraged to do their own financial feasibility assessment.
- Government or regional organisations should make available broader (national, regional) scale assessments and comparisons to potential investors and farmers.
- There are opportunities for private public partnership in assessing cage culture potential.
- Government or other organisations should develop general guidelines for business planning for cage aquaculture.
- In general interested investors should do their own piloting; however, by undertaking thorough pilot trials, government research institutions can play a role in attracting investment and reducing business risk.
- Government research institutions should sell piloting and applied research services to the private sector and where possible engage in public private partnerships to undertake such studies (generating publicly available information).
- Donor organisations and regional institutions can assist in research strategies, co-ordination and collaboration – and possibly highly focused applied research.

Input costs, quality and supply

- Limit import duty on imports of cage materials.
- Government/agencies/NGOs should develop and disseminate information and guidance on cage design.
- Government/regional organisations should develop a national/regional strategy for broodstock holding and management.
- Government should develop and implement seed quality certification/licensing in parallel with hatchery training.
- Government should assess the status and alternatives of wild caught seed and develop appropriate policy and management.
- Government should assess and review the status, potential, allocation and management of existing trash fish and fish meal resources, and identify alternatives for quality fish feeds.

Distribution and markets

- Aquaculture development should be accompanied by market promotion to stimulate demand by private sector.
- Local and National Government has an important role in health and nutrition issues. Fish should be promoted as components of health and nutrition campaigns.
- Local government may have a strategic role in fish market development and infrastructure.
- There are important roles for producer organisations and NGOs in market development and demand stimulation.
- Government should identify bottlenecks in fish marketing and develop strategies to address them.

Rights and access

- Involve communities and stakeholders in the early stages of business planning.
- Zonation of water bodies should be explored as a tool to reduce conflict, especially for larger scale operations.
- Local zonation or siting guidelines/conditions may be more appropriate for smaller scale enterprises.

- Beach management units and similar institutions may play an important role in allocating resources and setting conditions at local level.
- Concessions paid to beach management units may serve as a mechanism to benefit local community and fund improved management or infrastructure.
- Public awareness and education programs should be launched to promote cage culture development and reduce conflict.

Promoting entry – finance and capacity building

- Government should develop a positive policy environment for private aquaculture credit schemes.
- Government/aid agencies/NGOs/private finance institutions should explore innovative/alternative financing schemes taking full account of the particular characteristics of cage aquaculture.
- Research institutes should carry out more relevant practical applied research to the needs of the sector.
- Research institutes should be encouraged to work with private sector farmers to address practical constraints and disseminate learning.
- Growth in private sector customer service providers should be facilitated.
- Private sector developers should invest in capacity building.

Structural issues and poverty alleviation

- National government should monitor and analyse development trends and structural problems in aquaculture development, and focus joint private-public sector energies in their solution.
- Permission to farm should be subject to conditions relating to fair employment practices and promotion of local employment and skills.
- Opportunities for out-grower schemes should be explored and promoted as part of business planning guidance.

Annex 1 – Agenda

Wednesday 20 October

08:30-09:30	Registration
09:30-10:30	Opening Session
10:30-11:00	Coffee break
11:00-11:15	Housekeeping
11:15-11:30	Background for the Workshop (Moehl)
11:30-12:00	Cage culture: a challenge (Hambrey)
12:00-13:30	Lunch
13:30-14:15	The Norwegian experience (Grottum)
14:15-15:00	The Italian experience (Cardia)
15:00-15:30	Coffee break
15:30-15:45	Cage culture in Uganda
15:45-16:00	Nile perch cage culture (Gregory)

Thursday 21 October

08:30-09:30	Small-scale cage culture (Hambrey)
09:30-10:30	Asian overview (Phillips)
10:30-11:00	Coffee break
11:00-11:30	Development and drivers of cage culture (Rana)
11:30-12:00	Cage culture in Zimbabwe
12:00-12:15	Cage culture in Kenya
12:15-12:30	Cage culture in Malawi
12:30-14:00	Lunch
14:00-14:15	Cage culture in Zambia
14:15-14:30	Cage culture in Ghana
1430-14:45	Organization of Working Groups (Chair)
1445-17:00	Working Groups

Friday 22 October

08:30-11:30	Working Group discussions
11:30-17:00	Field trip

Saturday 23 October

08:30-10:00	Summation within working groups
10:00-10:30	Coffee break
10:30-12:00	Presentation of Working Group results
12:00-13:00	Outlining the way forward (Chair)
13:00-15:30	Lunch
15:30-16:30	Adoption of way forward (Chair)

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Annex 3.1 – Working Group on Environmental Issues

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
1. Impacts			
• Externalities on cage farming operations: all other activities within the water catchments influence the cage culture environment and thus the cage culture enterprise. • Internalities: site selection and management could reduce possible impacts of cage culture effluents on environments.	• In common with other food production systems, cage fish farming generates waste which may unduly impact on the environment	• Cage culturists must have national associations (as in salmon producing countries) to represent their industry with one voice, e.g. in discussion with governments and environmental regulatory agencies • Knowledge and technology transfers should assist farmers in optimizing production and minimizing impacts of their operations on their environment • Knowledge and technology transfer activities which assist farmers in optimizing production and minimizing their operations' impact on the environment • Activities external to the cage culture whose impacts on environment (land use practices, water transport system) must be accessed and assessed • Cage culturists should establish networks to share experiences on environmental management	• Environmental concerns about cage culture should be considered within the context of overall environmental conditions in a waterbody • Cage farmers and businesses should work with communities and regulators to improve environmental conditions in waterbodies, caused by deforestation, agricultural pollution and erosion • Targeted short-training programmes
2. Planning			
• Cage culture should be located in suitable sites within the capacity of the environment to maintain environmental quality and sustain farming • Information on environmental conditions and environmental standards is required as a baseline for planning of cage culture development, environmental assessment and decision-making • Africa requires a knowledge base on waterbodies to assist in making development decisions on cage aquaculture	• Development of cage culture requires a regulatory framework, based on environmental standards and assessment of environmental impacts	• Prepare plans for cage culture development to identify suitable sites and zones where farming is permitted • Define capacity for cage farming within each designated farming zone • Include in plans zones for small-scale and larger-scale developments • Conduct environmental monitoring of cage culture sites and the waterbody to determine environmental changes and to adjust plans and operations as required • In shared waterbodies, collaborate with neighbouring states to conduct strategic environmental assessment and to develop and agree joint management plans for cage culture • Conduct strategic environmental impact assessments of cage farming in large waterbodies that provide a basis for planning of cage aquaculture • Include costs of environmental monitoring within licences/rents for cage culture operations	• Governments should establish environmental standards as well as consistent and clear criteria for EIA to benchmark and make comparisons • Capacity of large African lakes should be assessed and strategic management plans be developed for cage aquaculture; donor and technical agencies should assist governments in such assessments if required • Share experiences on environmental standards, assessments and management plans for cage culture, such as through electronic newsletters and other publications • Build capacity and skills in environmental assessment and planning for cage culture development; request FAO to organize a regional course to assist in building skills • Develop a set of best management practices (BMPs), covering relevant environmental and quality standards, and representative of cage culture systems in Africa, for widespread sharing; organize national training on the BMPs supported by governments, regional organizations and NGOs

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
3. Permits/licences			
• Need for clear criteria and standards for issuing permits • Present situation involves long and cumbersome administrative processes • Many agencies involved in the permitting process, often with lack of any one agency taking primary responsibility for processing permits • Reasonable licensing periods are required to provide security of investment • Harmonization of tenure arrangements for land and water use • Customary practices for water and land tenure influence permitting processes	• There should be a permitting system for cage culture farms organized in an efficient way with clear administrative responsibilities	• Governments should apply a permitting/licensing process for cage culture • Apply clear standards and performance criteria for assessing permit/licence applications; ensure that licences are processed within a specified period of time • Licensing periods should be of sufficient time period to allow for long-term investment, but subject to reviews of performance against environmental criteria • Governments should identify one agency responsible for permitting/licensing (the actual agency concerned would be designated by each country, e.g. Dept of Fisheries) • Individual permits/licences should be provided for farming within a designated area or zone (refer to lesson 2) and allow for movement of cages and fallowing of sites as necessary within the zone • Support environmental monitoring of the waterbody with revenues from permits/licences • Conduct environmental monitoring as part of the permit/licence agreement	• Generic standards for permits/licences should be prepared • Share knowledge on permitting/licensing standards • Undertake research to investigate ways of generating revenue/taxing emissions from cage aquaculture to support environmental improvement
4. Feeds			
• Environmental impact influenced by feed formulation and feeding practices • Species selection and polyculture influence waste loadings • Lack of knowledge on feed formulation and feed development • Lack of suitable quality feeds is a constraint to cage aquaculture	• Feeds from intensive cage culture are the major source of environmental contamination	• Select species suitable for the waterbody or zone, for cage culture • Encourage polyculture and selection of species mixes that efficiently use feed resources and minimize waste • Encourage use of farm-made feeds and recycling of local resources for small-scale cage aquaculture • Encourage large-scale cage aquaculture to use quality extruded feeds to safeguard the environment and improve feed conversion ratios (FCRs) • Encourage due-diligence appraisal to identify choice of species and feed availability (understand links between species, feed and business) • Develop cage culture using good quality feed and local materials • Support traceability of feed supplies to encourage high standards • Formulate feeds to reduce discharge of wastes to the environment • Improve FCRs by good feeding practice and do not feed with poor quality food • Do not use feed ingredients for fish competing with human food requirements (e.g. fish protein)	• Research on feed formulation and feed management in cage aquaculture (e.g. use of local ingredients, formulation of feeds, farm-made feeds, environmentally friendly use) • Share knowledge on feeds and research outcomes in the region • Governments should develop feed standards to provide guidance for feed formulation and avoid contamination problems in farmed fish • Prepare guidelines on feed formulation and feed management for wide dissemination in the region • Impacts of trash fish use on the ecosystems should be carefully evaluated through research

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
5. Diseases			
• Reducing disease risk from poor management and environmental conditions • Responsible use of chemicals, risks of product contamination and human health problems from irresponsible use of chemicals • Reducing risks of introducing new and serious diseases	• Fish disease control and health management is required to reduce risk of fish disease outbreaks in cage aquaculture	• Practise fish disease prevention, by maintaining healthy culture environments (such as suitable quality feed, appropriate stocking densities, good water quality and using quality fry and fingerlings) • Minimize the need for use of chemicals by practising fish disease prevention • Use only approved medications/chemicals where absolutely necessary ideally with advice from a fish health professional • Do not use banned chemicals • Practise responsible movement of fish, taking precautions to reduce risks of introducing new diseases • Incorporate traditional knowledge and experience in maintaining fish health	• Governments should disseminate information on banned chemicals and responsible use of chemicals • Within the permit/licence systems governments should include references concerning allowed chemicals • Governments should introduce regulations on health management and responsible movement of fish; encourage cooperation among countries to develop common regulations/approaches • Encourage enforcement of existing hygiene standards
6. Biodiversity			
• Risks to aquatic biodiversity from introduction of exotic species • Impacts of transferring species between watersheds and within the region • Use of indigenous species for cage culture • Lack of agreed protocols for introductions of alien species	• Introduction of alien species (exotics) risks ecological impacts and introduction of disease, and should be strictly regulated	• Identify suitability and encourage use of indigenous species for cage aquaculture • Encourage breeding programmes to support use of indigenous species • Assess risks if considering introductions of non-indigenous species	• Research on development/improvement of indigenous species for aquaculture should be encouraged and monitored by regulatory agencies • Encourage partnerships between regulatory agencies and fish farming businesses in regulation and use of indigenous species • Development of regionally agreed protocols for movement of indigenous species • Development of regionally agreed protocols for introduction of exotic species and responsible transboundary movements
7. Information/communication			
• Lack of information on cage culture operations and accessibility of information to the public generally because of biosecurity measures by operators • Lack of locally generated information and of its availability to local environmental agencies leading to overcautious application of external information sources to protect the environment	• Adversaries of cage farming successfully created a globally negative image of industry	• Associations and operators should prepare to appropriately correct the impressions through education and communicate with their relevant policy decision-makers and their communities • There should be a continuous process of image building with policy decision-makers and communities • Associations should have multidisciplinary groups responding to occasionally adverse publicity of the industry	• Cage culture operators and associations should deliberately create controlled public information awareness on their operation and products

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
8. Policy			
• Aquaculture and more specifically cage culture have been largely outside the remit and operations controlled by institutions responsible for inland and marine water resources and management • Aquaculture does not feature in many inland and coastal water resource management plans; even where included in plans implementation is weak	• Lack of institutional arrangements and coordination among the public sector institutions to establish regulations necessary to be responded by cage culturists	• Policy and strategic planning for cage culture have to address the issues of institutional arrangements, mechanisms and coordination • Resource use plans should identify priority areas for cage culture zones in a country which then have supporting policies	• Arrangements to control the use of international waters should be revised to accommodate issues related to industrial cage culture • In view of complexities involved in using international waterbodies for cage culture the industry should be initiated in appropriate national waters especially those with least potential conflicts amongst users, in so far as possible • Institutional arrangements among regulatory bodies must be emphasized and streamlined to assist cage culture operators in obtaining either permits or licences • Water use policies need appropriate reversions to accommodate cage culture development • Environmental management relies on staffing of farms by good calibre managers and workers; the skill base of the sector in Africa therefore needs to be developed • Awareness of cage culture also needs to improve among administrators and decision-makers
9. Capacity building			
• Building the skill base for sustainable development of cage aquaculture in Africa • Building capacity among institutions to support skill development	• Skilled people within regulatory and scientific bodies and cage farming operations are essential to support development of a sustainable industry		• Development of national and coordinated regional training programmes and exchange of experiences, to support capacity building and skill development • The recommendations included above should be integrated/respected when elaborating national and regional skill development programmes

Annex 3.2 – Working Group on Biological and Technical Issues

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
• Capture fisheries	• Cage farming can increase fish populations around cages and can therefore increase fishing activities • Use of chemicals and feed can have a negative impact • Contamination of natural stocks by escapees • Increased nutrients resulting from cage farming can improve or reduce capture fisheries • Cage farming will change the ecosystem; this change can be both negative and positive	• Prevent fish escapes through physical barriers and good management • Select sites carefully to maximize benefits and minimize negative impacts, then monitor rigorously • Regulate use of feed and chemicals	• More research on the impact of cages on capture fisheries • The authorities should: i. survey and model and then ii. produce maps showing suitable zones for cage farming
• Control of fish health	• The risk of transfer of pathogens between cages and the wild is increased either way	• Stock healthy fish and keep them healthy through proper management • Treatment should be regulated (professionally) • Use oral administration techniques where ever possible	• Regulate use of chemicals • Develop comprehensive support services
• Use of non-indigenous species	• Fish will escape from cages, non-indigenous can have far reaching consequences • Marginalization of use of indigenous species, e.g. common carp in Malawi and Kenya	• Avoid use of species not authorized by the authorities • Use indigenous species where possible • Sterilize non-indigenous if possible • Prevent fish escapes through physical barriers and good management	• Governments need regulatory frameworks
• Feeds	• Some countries have insufficient appropriate raw materials • Transport of feed can be very expensive • Poor quality feed is not worth using • Poor feed management can increase production costs and can be a source of pollution	• Develop good quality feed • Use extruded or cooked feed • Develop proper feed application regimes • Produce feeds locally if possible	• Encourage local good quality animal feeds production • Encourage people to grow feed materials
• Seed	• No seed, no aquaculture • Poor quality seed results in low yield in aquaculture	• Seed must be available year round, locally in good quality and at an acceptable price • Use quality seed bought from proven suppliers • Stock feed trained fingerlings of uniform size • Avoid inbreeding • Use government approved species • Use marketable species	• Encourage research and development of good quality hatcheries • Exchange of technology and information • Regulate candidate species

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
• Mechanics of production	• Cage and system design will depend on the species farmed, the production system used, the site and the scale of operation • Site selection and system design make all the difference • Maintenance of cage infrastructure and nets is critical to success • Cage design must allow easy fish sampling, monitoring and mortality removal • Use good accurate stock control • Cages should be designed for worst weather conditions • Cage culture needs to be supported by appropriate boats, vehicles and onshore infrastructure	• Design systems professionally • Carry out thorough EIAs • Cage design should be specific for species, production type, site and market • Cage sites should be accessible to infrastructure, supplies and markets • Use biological control instead of antifouling chemicals • Use cages designed to minimize fish handling • Use passive grading techniques • Selection of site that minimizes interaction with wildlife, humans and pollution • Design of systems should maximize fish welfare • Design and training should maximize workers' health and safety • Cage culture should be encouraged through research, commercial demonstration and technical support	• Encourage pooling of support infrastructures and resources for small- and medium-scale systems • Authorities could provide technical support services to help with design • The authorities should first survey and model and then produce maps showing suitable zones for cage farming

Annex 3.3 – Working Group on Socio-economic Issues

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
1. Financial assessment and management			
Need for rational assessment of pond and cage culture potential: • technology • cost • benefit • production (see sector planning above)	• Seed, feed and market lessons learned from pond culture will be relevant for cage aquaculture • Small-scale producers lack capacity and resources to do it well	• Do it, and do it well • Draw lessons from past experience with pond aquaculture • Compare cage culture objectively with alternatives (including pond culture) • Explore opportunities for private–public–partnership in assessing potential	• Individual farmers, irrespective of socio-economic status, should be encouraged to do their own analysis • Government to make available broader (national, regional) scale assessments and comparisons to potential investors and farmers
Business planning: • markets • production feasibility • financial feasibility • projections • finance	• International markets may be unreliable (standards, antidumping) • Apparent price premium of international markets may be outweighed by costs of market access (standards, reliability, freight, etc.) • National markets have great potential, especially close to growing urban centres • Costs always higher than expected; returns always lower • Local factors – such as predators, water quality, vandalism/theft – can radically reduce financial returns Purely private technical piloting may result in mistakes being duplicated by others?	• Undertake technical piloting before investment in large-scale operations • Overestimate costs, underestimate profits • Ensure a scale adequate to address potentially critical economies of scale and lack of competitiveness • Explore opportunities for private–public–partnership in assessing business feasibility • Consider: – cage design and costs in relation to local conditions (wind, waves, currents, actual and potential predators); – seed cost, source and quality; – feed cost, source, quality; opportunities for on-site or external formulation; – community interests; – fish health/disease management; – stocking/harvesting strategies.	• Government or other organizations to develop general guidelines for business planning for cage culture • Interested investors should do their own piloting, although: – government research institutions to pilot technologies in some situations – may attract investment; – government research institutions to explore options for promoting and selling piloting and applied research services to private sector; – government research institutions to engage in public–private–partnerships to undertake piloting and applied research (generating publicly available information); – government research institutions should support private sector investors through capacity building (see capacity building); – Donor organizations and regional institutions to assist in research strategies, coordination and collaboration – and possibly highly focused applied research.

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
Finance: • credit provision • procedures and allocation – screening; link to business planning	• Government • credit schemes tend to fail • Subsidies can undermine sustainability • Government policy affects nature and extent of private sector financing • Government funds can be effectively channelled through local NGO (e.g. micro-credit) and private sector financing schemes • Finance institutions lack understanding of aquaculture (especially working capital requirements, income cycles, etc.) • Interest rates often too high	• Single digit interest rates • Promote aquaculture skills as a form of collateral for finance?	• Government to develop positive policy environment for aquaculture credit schemes • Government/aid agencies/NGOs to explore innovative/alternative financing schemes
Cost effective cage construction: • design and materials • material costs • sourcing materials	• Sometimes best to use local materials • Sometimes best to import • Can often adapt foreign design for local conditions or using local materials	• Thorough appraisal of design and material options fully taking into account the local conditions	• Limit import duty on materials • Government/agencies/NGOs to develop and disseminate information and guidance on cage design
2. Increasing returns			
Market access and information	• International markets may be unreliable (standards, antidumping) • Apparent price premium of international markets may be outweighed by costs of market access (standards, reliability, freight, etc.) • National markets have great potential, especially close to growing urban centres • Market access/distribution systems often develop spontaneously – but not always • Mobile phone commodity price indexes useful	• Explore local and regional markets first • Encourage women's involvement in marketing • Stimulate market demand; facilitate network development	• Demand-led market promotion by government and private sector • Government to identify bottlenecks in fish marketing • Review the role of local government in fish market development/infrastructure?
Quality standards	• Standards should be appropriate to the market	–	–
3. Capacity building			
Building on the past: • making use of existing facilities • learn from past experience	–	–	–
Human resources: • inexperience • commitment	–	–	–

Key issues	Lessons learned	"DOs and DON'Ts"	Recommendations
Organization, cooperative action: • training needs • marketing • sharing information and experience	–	–	–
Role of government: • technical assistance; • building local capacity • policy/regulatory framework	–	–	–
4. Social issues			
Social assessment (sociocultural constraints to cage culture): • education • culture • tradition	• Cultural taboos about fish declining • Preferences for "capture fish" can exist, based on size, taste, species • Development of local markets , (rather than export markets), may reduce likelihood of social conflict, or increase it if cage farming production results in local price declines	• Fish should be promoted as components of health in nutrition campaigns • Stimulate demand by product presentation and advertising • Producers to be more involved in market development • Target support to women in fish marketing	• Role for producer organizations and NGOs • Capitalise on existing capacity: government and civil society institutions, e.g. women's groups, extension workers, community development organizers CDOs • Local/national government: health and nutrition issues
Access: • competition for resources • community owned water resources, traditional uses and access • security	• Plenty of examples of fishermen/aquaculture conflicts • Legal status of waterbodies important, e.g. foreign investments on common properties may be illegal • Generally, fishermen don't make good fish farmers • Suspicion of government by many fishing communities can increase tensions • Cage culture tends to be blamed for all future lake/stock problems	• Involve communities in early stages of development • Zoning for large-scale operations may reduce conflict situations • Guidelines for smaller producers • Public awareness and education programmes • Concessions paid to beach management units for community development	• Government zonation for macro-scale and large investment • Beach management units • Who resolves conflict situations?
Economic planning: • critical mass, development thresholds • priority areas or zones • sector profitability • infrastructure? • marketing • opportunities for the poor – equity and scale issues	• Large investors can be persuaded to behave in ways that ensure local benefits continue/increase (e.g. "net" increases in fish supplies) • Economic opportunities may exist for poor people as service provider for cage aquaculture (e.g. net making, input supplies) • Some lessons from pond culture are also relevant to cage culture (e.g. marketing) • Targeting extension efforts to high potential clients works better than blanket/group approaches • Farmer–farmer information exchange is relatively high because of the clustered nature of small-scale producers and opportunities for the rapid evaluation of the effects of management	• Hiring and training of local people in large operations • Outgrower schemes should be promoted • Promotion of local support industries • Use of local materials encouraged • Analysis of probable constraints to cage aquaculture • Equal employment terms for employees • Evaluate a range of scales of investment and technical options	• What can government do to stimulate local entry into cage farming? • Research institutes to carry out more relevant research to the needs of the sector • Customer service providers

Regional and technical reviews and presentations

A brief review of small-scale aquaculture in Asia, its potential for poverty alleviation, with a consideration of the merits of investment and specialization

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ABSTRACT

Drawing on the research undertaken by the Department for International Development (DFID) CAGES project and subsequent work for the Mekong River Commission, this paper briefly reviews small-scale cage aquaculture in some parts of Asia and its potential as a tool for poverty alleviation. The CAGES research in Bangladesh identified a set of criteria for assessing suitability of an enterprise for poverty alleviation and concluded that the small cages developed by CARE Bangladesh scored highly against most criteria. Work in Viet Nam also suggested that family-scale cage culture was an important contributor to poverty alleviation and economic development. Since the research ended, cage culture has continued to flourish in Viet Nam – indeed so rapidly in some places that environmental quality is threatened – but very small-scale cage culture has probably declined in Bangladesh. Several possible reasons for this are presented and discussed, including the absence of appropriate pro-poor extension systems capable of delivering flexible extension advice, the quality and availability of seed and feed, the relatively high production costs compared with pond culture and the real opportunity costs of labour. Another possible, if controversial, explanation closely related to the labour issue is that very small cages represent too small an investment (in both time and money), coupled with too limited and variable a return. It is simply not worth the bother, even for poor people, to look after the stock. The rather higher investment and return in Viet Nam on the other hand allows for whole families to "live" above cages. The investment forces commitment and the return rewards that commitment – and the entire livelihood of the household is transformed. This goes against the traditional development view that very low investment systems are essential for poor people, and that new enterprises must "fit in" with peoples livelihoods and other activities. A simpler approach based around a robust appraisal of financial feasibility and comparative advantage may be more appropriate. Small may be, but is not necessarily, beautiful. And fitting in with livelihoods is all very well, but development is also about significant increases in income and the transformation of peoples' lives.

SMALL SCALE CAGE CULTURE IN BANGLADESH

The CARE-CAGES project in Bangladesh assisted poor villagers to develop small-scale cage culture practices to produce a range of freshwater species which could provide food for home consumption or earn income. Species included tilapia, Chinese carps, catfish (*Pangasius* spp.), silver barb (*Barbodes gonionotus*) and the freshwater prawn (*Macrobrachium rosenbergii*).

Technology

The technology consists of very small cages, 1 cubic metre in volume, which can be made for about US$5 each. Depending on the species and local circumstances, the nutrition provided for growth is usually fresh natural foods gathered from the wild (such as duckweed, snails, etc.) and household vegetable wastes. Some low cost feeds are bought in by the households, typically rice bran and oilcake, but these costs are minimal. Occasionally, and particularly in the case of *Pangasius*, the diet may be supplemented with commercially available compound feeds. In most cases a mixture of diets is offered, according to their availability and needs of the fish. Growth is rapid in the warm climate of Bangladesh and the fish attain marketable size within 3–9 months, providing farmers with a rapid return on their investment and labour and reducing risk. Depending on species and grow-out period, the annual gross income per cage is between US$20–100.

Potential for poverty alleviation

Any new enterprise or technology has strengths and weaknesses in terms of its potential for poverty alleviation. At the time of the research and during project review and taking into account the particular nature of rural poverty in Bangladesh, we assessed the potential as shown in Table 1.

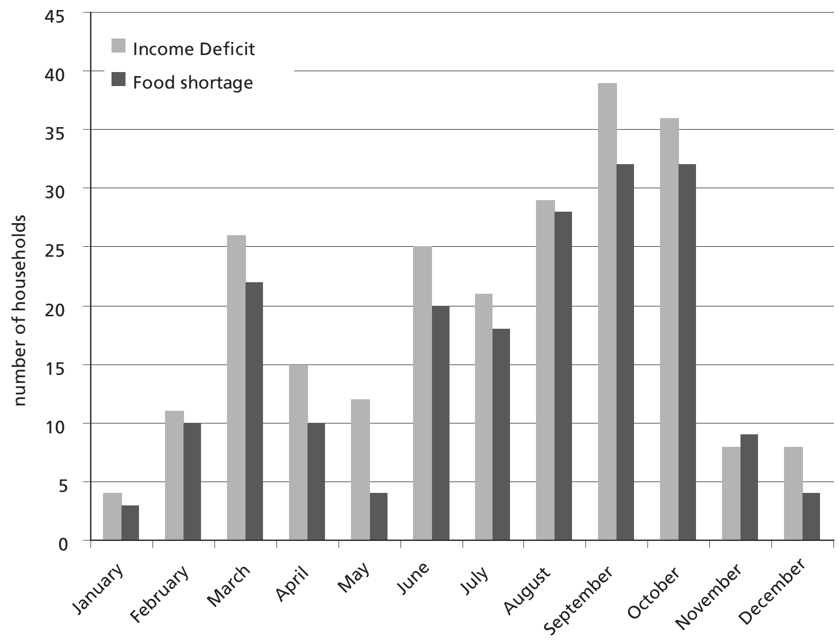
The seasonality of investment and production/income from cage culture was seen as a particular strength. Labour inputs correspond to the period of labour surplus; investment is required mainly at time of maximum income from rice. Income and crop occur in a period of income and food shortage (Figure 1). In other words, the technology fits with and reinforces traditional coping strategies of investment in livestock when times are good and realizing the asset when times are hard.

The weakness of economies of scale in the use of labour was not seen as a problem by the project. The real opportunity cost of labour for the very poor may be low, and cooperation, which was encouraged, can greatly reduce labour requirement.

TABLE 1
Assessment of strengths and weaknesses of cage culture systems in Bangladesh.

Strengths	Weaknesses
• Little if any land required.	• Economies of scale in the use of labour.
• Low investment – high return. Or rather high return per unit investment and potential for small-scale start-up.	• Economies of scale in cage costs.
• Seasonality of labour use, investment and financial return complements that required for rice cultivation.	• Economies of scale in marketing.
• Flooding risk less than for some other enterprises.	• Significant risk of loss: 1. poor stock may die soon after stocking; 2. older fish can die rapidly in unfavourable water quality. • Vandalism and jealousy.
• Can exploit family labour and natural food resources or kitchen waste.	• May deplete local natural food resources and may compete with other uses for household waste.
• High price for fish; strong predicted demand.	• New skills and knowledge required.
• Existing fish markets and “transactions infrastructure”.	• Production costs higher than in ponds.
• Flexibility – scale, species, feeds, investment, intensity, cropping patterns. An adaptive suite. A ladder?	• Access to private or public waterbodies not always available and rarely secure
• Well placed to service widely dispersed rural markets.	

FIGURE 1
The annual cycle of deprivation and vulnerability amongst the rural poor in Bangladesh (data from CARE Bangladesh)



The higher costs (per kilogram product) of smaller cages, was considered to be more than compensated for by the low investment, the ease of handling and the marketing convenience.

Risk was considered to be a significant issue – especially in those areas where vandalism was common or where seed was of poor quality – but the project saw rapid reductions in losses as the project evolved, and most farmers did well. Nonetheless, significant numbers of farmers did fail, although the costs of failure were born by the project in the early stages.

Many participatory assessments of potential at local level were undertaken, most of which were very positive, especially in relation to the extreme poor and women.

CAGE AQUACULTURE IN KHANH HOA PROVINCE, VIET NAM

Marine and brackish water aquaculture is developing rapidly in Khanh Hoa Province, in south-central Viet Nam. It started with brackish water pond culture, mainly for marine shrimp (*Penaeus* spp.) and also grouper (*Epinephelus* spp.), but in recent years the cage culture of grouper and especially spiny lobster (*Panulirus* spp.) has developed very rapidly.

Technology

Cage culture production is dominated by individual family enterprises which own and operate one or more cages in coastal lagoons and sheltered bays. Cages are typically between 10 and 30 cubic metres in volume, constructed with synthetic netting stretched over bamboo frames, hanging from wooden stakes driven into the seabed or floating rafts anchored in the seabed. Families usually aggregate their cages into groups, according to the quality and convenience of each site, which facilitates transportation, security and the sharing of labour.

Seed for both grouper and lobster are harvested from the wild. The seed, typically between 3 and 10 cm in size, is usually caught in traps by local fishermen, although

TABLE 2
Assessment of strengths and weaknesses of family-scale cage culture in Viet Nam.

Strengths	Weaknesses
• No land required.	• Dependency on wild seed.
• Modest investment, high return.	• Dependency on trash fish.
•	• No significant regulation.
• Resilient to usual livelihood threats of flooding, erosion and habitat destruction.	•
• Little disease.	• Disease now increasing.
• Well established distribution and marketing networks – originally based on capture fisheries.	• Modest investment still too high for the very poor.
• High upstream multiplier effect amongst the poor engaged in feed and seed collection.	• –

juvenile lobsters are occasionally taken by hand. The diet provided is trash fish and shellfish, which is either purchased from dealers at local markets or caught locally and used directly. The majority of fish and lobster is sold and marketed live, mainly through local buyers who sell on to the major exporting companies based in Ho Chi Minh City. Disease is not a serious issue, although it has begun to increase in recent years.

Potential for poverty alleviation and improved quality of life

Strengths and weaknesses

As for small-scale cage culture in Bangladesh, family-scale cage culture in Viet Nam has strengths and weaknesses in terms of its suitability for poverty alleviation (Table 2).

Overall, most of the poor people not already engaged in cage aquaculture were keen to enter, suggesting that the strengths are significant, and that the main weakness or constraint is the cost of entry to the business.

Contribution to the needs and aspirations of poor people

In Viet Nam, we worked with both cage farmers and non-cage farmers to try to establish what they wanted from the activities and enterprises with which they were, or might become, engaged. We did not use the standard livelihoods framework, which is academically conceived, but rather developed criteria with people on the ground. How did they judge/assess income generating activities?

After a great deal of discussion between local scientists and villagers, the following important criteria were elicited:

- good physical environment (shelter, comfort, safety);
- interest and stimulation;
- low stress;
- sense of progress or creativity;
- security of income or employment;
- building on/compatible with tradition, habit, experience;
- high output (catch, production);
- reliable inputs (quality, availability, etc.).

A range of alternative income generating activities open to coastal villagers was then assessed against these criteria by the villagers themselves and an overall un-weighted score was generated. The results are shown in Figure 2. In practice, different respondents accorded differing weights on the various criteria, so such an aggregated score should be treated with caution; but nonetheless the indications are that cage farming of grouper was perceived very positively – by both those already engaged and those keen to enter – when compared with the main alternative activities.

Financial returns

A more objective assessment of financial returns was also made, by developing simple financial models for each type of enterprise. The results were then simplified to generate star ratings for each type of enterprise as shown in Table 3.

Constraints to entry

In practice, many people wished to start cage aquaculture but had not done so for two main reasons: lack of finance and uncertainty about risks and returns. Since the research was undertaken, cage culture – especially of lobster – has boomed. This appears to confirm research findings on the attractiveness of the enterprise, but raises the question as to where the finance has come from. The answer is self-evident: when something is financially viable, capital will be found, but probably not by the poorest members

FIGURE 2
Rating of different coastal income generating activities (IGAs) against a set of locally derived criteria.

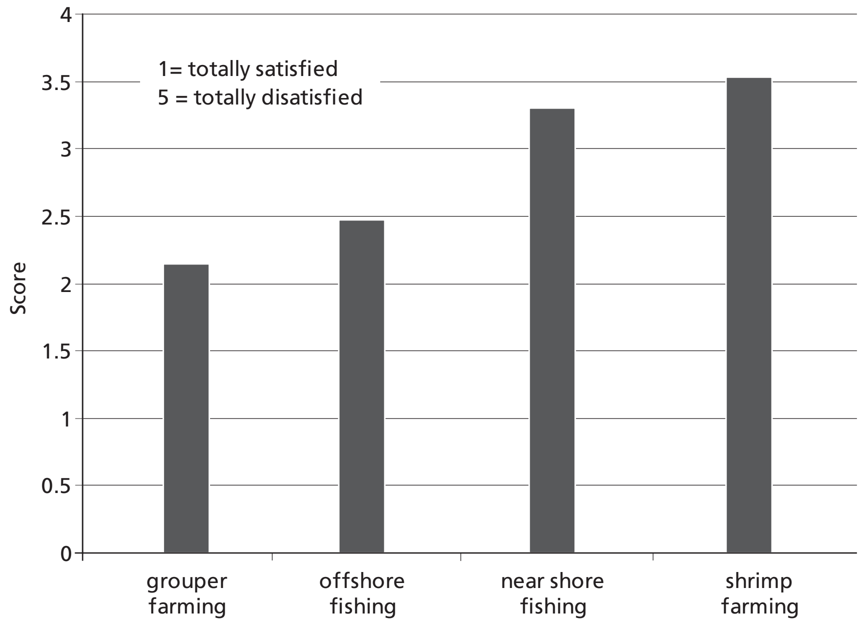


TABLE 3
Summary comparison of financial and economic indicators for alternative enterprises in the coastal zone

	Lobster culture (cages)	Grouper culture (cages)	Semi-intensive shrimp farming	Offshore fishing	Inshore fishing (net)
Profit/kg	***	**	**	na	*
Profit margin	**	**	**	*	*
Return on investment	***	**	**	*	*
Return to labour	***	**	***	**	*
Employment/kg	***	**	*		*
Start-up investment[1]	***	***	*	*	**
Investment/job	***	**	**	*	**

* = unfavourable; ** = favourable; *** = very favourable
[1] This includes capital investment and – for farming activities – working capital (for feed, seed, etc.) required for production of the first crop.

of society. A recent visit to Khanh Hoa suggests substantial “outside” investment in lobster culture, but local people are employed or take a share of the returns.

Risk

Disease is still a relatively minor problem for cage aquaculture of grouper and lobster, although it has increased substantially in recent years at some sites (see next section). Loss of stock through early mortality, cage damage or theft/vandalism is also unusual. This relates largely to the nature of the enterprise. The scale and returns are such that it is usually worthwhile for one or more family members to live above the cage or cages at all times. Cages are typically sited in large groups so that neighbours can also keep a watchful eye and, where appropriate, share in the work.

Sustainability

It is unfortunate that any suitable and successful enterprise is likely to develop rapidly, along with a raft of social and environmental impacts. The sustainability of seed and feed supply are both questionable in the medium term, and dense development is also beginning to impact the environment. A follow-on study has monitored water quality in an open lagoon system subject to rapid cage culture development and demonstrates clearly a steady decline in water quality – in parallel with a steady increase in disease incidence. Our own very simple mass balance calculations suggested that environmental capacity would be exceeded in 2002 and the water quality data confirm this (Figure 3). Similar trends were found for total N and for organic matter accumulation.

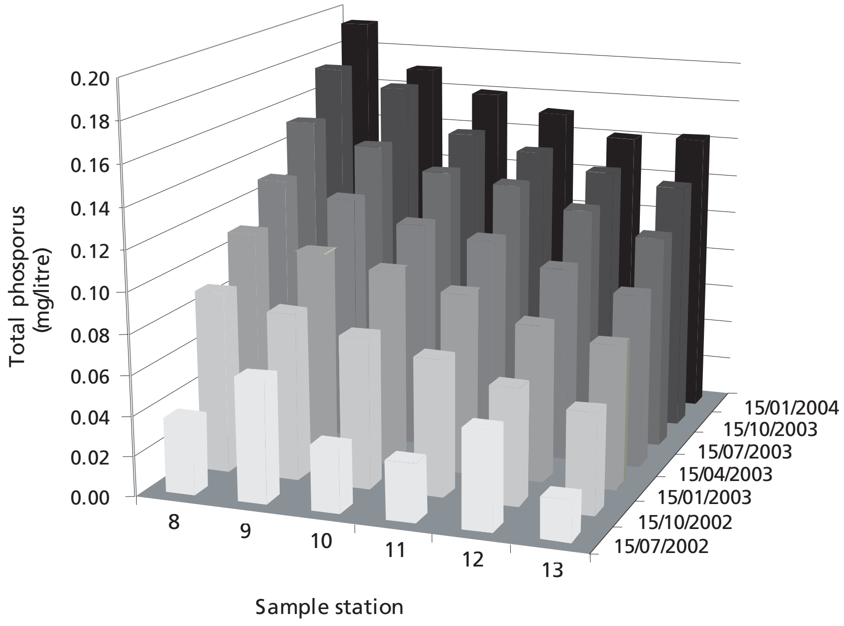
Clearly, this is unsustainable and we are trying to gain agreement as to how to limit nutrient discharges – through better practice or through limited entry – or how to reduce the severity of impact through better siting or reduced cage density.

SOME OTHER EXAMPLES

It is worth briefly referring to some other systems which were examined as part of a research consultancy for the Mekong River Commission and funded by the Danish

FIGURE 3

Nutrient (total phosphorus) concentration gradient and trend in Xuan Tu Bay (note that sample stations 1-7 covered a transect at 180 degrees to those shown. This transect showed a similar trend)



International Development Agency (DANIDA). The study was focused on financial analysis and risk assessment of selected aquaculture and fishery activities in the Mekong Basin.

Cage aquaculture and fishing in Lao PDR

As with other aquaculture systems, it is very difficult to give indicative returns because the technology is new and varied, and standard management practices are not established in most cases. At a small scale, scale factors, especially in relation to labour use and return on labour are very significant. Also in this case only limited data were available. Of the systems examined, the most consistent was for intensive tilapia where a standard semi-commercial package is now available.

One great attraction of the aquaculture systems is their flexibility in terms of scale, intensity of inputs, collection or purchase of inputs and range of species from mainly herbivorous to carnivorous. Start-up costs are modest, especially if captured seed and feed is available, or where herbivores/planktivores are reared. The tilapia systems require more investment, but returns are more predictable and operations can be set up in locations where wild seed and trash fish are not readily available.

RESERVOIR FISHERIES, CAGE CULTURE OF GRASS CARP AND ALTERNATIVE ACTIVITIES IN DAK LAK, VIET NAM

A summary of the financial characteristics of some of the activities studied in Dak Lak Province is presented in Table 5. The most attractive enterprises are the small stocked reservoir (Ho 31) and the lift net fishing in Ea Kao, a medium-sized stocked reservoir. Prior to disease, cage culture grass carp generated consistent returns to labour that were a little above market rates, but profit margins were very slender, and this, coupled with increased risk of failure, has led to its demise. Any resurgence would be dependent upon very high growth and survival rates, coupled with a ready supply of feed requiring lower labour input.

DISCUSSION

This brief overview offers a glimpse of the huge range of cage aquaculture activities to be found in Asia, and the widely varying success. Overall, however, cage culture is increasing, in some cases rapidly, and in many countries the poor are benefiting directly or indirectly. It commonly generates substantially higher returns than alternative activities.

TABLE 4

Presents a rough approximation and summary of the main financial features of the systems examined. In general, the cage aquaculture systems scored well against a range of criteria and appear to be more attractive than most available alternatives, including fishing and rice cultivation.

	Snakehead (purchased seed and feed)	Snakehead (captured seed and feed)	Intensive cage culture of tilapia	Silver carp	Pen culture	Fishing (gillnet, using small boat)
Minimum start-up capital (US$)	100–200	8–100	500–700	90	6 000	800
Length of crop cycle (years)	0.7	0.7	0.33	1	1–2	–
Payback period (years)	<1	<1	<1	<1	<2	6+
Net revenue (cash) per cage or enterprise (US$)	Negative to +70	50–200	300–6300	500?	13 000	<500
Return on labour (US$/ person-day)	Negative to 6	3–7	2–6	–	–	<1
Profit margin (%) (labour charged)	<20	50–80	5–40	–	–	–
Return on investment (%)	Negative to 500	200 +	100+	–	–	–

TABLE 5
Summary financial profile of selected activities in Dak Lak Province

	Capital investment per ha or unit	Annual costs (including labour)	Net revenue[1] per ha/yr; gear/ yr; cage/yr	Return on labour	Return on investment	Profit margin
Small stocked reservoir (Ho 31)[3]	–	584–926	323 to 1 498	9–28	-	26–68%
Gill net fishing Ea Kao reservoir	54[2]	327	-2 to 75	1.7 to 2.2	-3% to 137%	0–18%
Gill net fishing Ea Soup reservoir	121	703	-359 to -410	0.1 to 0.2	-297% to -340%	-104% to -140%
Lift net fishing Ea Kao	315	551	-427 to +1,086	0.1 to 5.8	-135% to +345%	-342% to +66%
Cage culture of grass carp (pre-disease)	137	207	9	2.3	11%	4%
Coffee production (2001)	455–721 (547)	191–394 (276)	-134 to +160 (-11)	0.5–2.4 (1.3)	-22% to +32% (-2%)	-111% to 32% (-28%)
Rice production (1 crop) 2001	NR	181–347 (232)	-91 to +90 (19)	0.5 to 2.5 (1.6)	NR	-100% to + 41% (-4%)

[1] Labour charged at market rates.
[2] Capital costs divided by the number of fishers in the team.
[3] No significant long term investment.

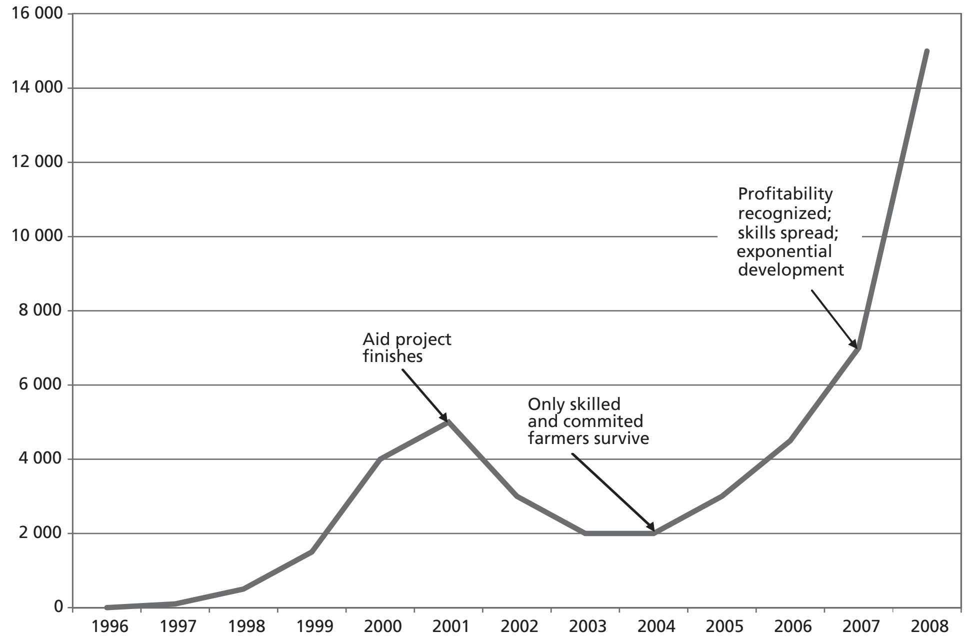
The review also raises some important questions in terms of the suitability of different kinds of cage aquaculture for poverty alleviation, and in particular the scale of enterprise and the level of investment. Most poverty alleviation specialists argue that the most appropriate income generating activities (IGAs) for poor people are low investment, ideally (if rarely) coupled with high return. They have argued that any new IGA should "fit in" with existing livelihoods and "coping strategies". The livelihoods context needs to be understood and suitable activities to be identified.

The CARE-CAGES project in Bangladesh was in many ways a classic example of this approach, with a particularly strong emphasis on minimizing initial investment to allow the poorest access to the technology (McAndrew *et al.*, 2000). Despite its apparent financial attractiveness and suitability for poor people, spread of the technology since project completion seems to have been limited and, if anything, there has been a decline, except perhaps for the nursing of *Macrobrachium*.

Such a decline is perhaps to be expected, and the development trajectory may be following the hypothetical curve shown in Figure 4. The extreme poor are least able to take advantage of new development opportunities, in terms of access to resources, finance, skills, education and markets. Projects such as CARE-CAGES seek to overcome these obstacles and provide intensive support to poor people willing to try something new. It is unsurprising that when this support is withdrawn that there is a decline in activity. If, however, the enterprise is financially attractive and also suited to the circumstances of the poor, one would expect that the decline will bottom out, and that the technology will begin to spread even without intensive support.

However, there may be other weaknesses of very small-scale cage culture that could limit its uptake by the poor and contribution to poverty alleviation in the medium and long term. Some of these – such as seed and feed quality – are relatively well aired and they will not be addressed here. Others related to socio-economic factors are more subtle and controversial but deserve consideration.

FIGURE 4
Expected pattern of development of a poverty focused development (number of enterprises per year)



Complexity

The first is that it is a relatively complex technology with a range of species, feeding and production cycle options. Small-scale cage aquaculture is not a single type of enterprise, but rather a suite of options appropriate for different development contexts and types of household. Although we flagged this up as a strength in our project review – a highly flexible and adaptable technology – it may in fact turn out to be a weakness. It will be very easy for poor people to choose the wrong option and make little money or indeed lose it. In the absence of high educational levels, intensive extension support is required to help appropriate uptake – where an advisor can sit down with a potential entrant to discuss the options and select the most appropriate for local and household circumstances. There is no simple extension message. The reality is that such an extension service does not currently exist and there is little prospect of it ever being developed. It would be extremely expensive and the overall national economic returns are likely to be limited.

This contrasts with the highly (over-?) successful marine cage culture systems in Viet Nam. Famers buy wild seed, and feed them with trash fish and shellfish. It costs quite a bit but you make good money. Anyone can work it out.

Investment, nurture and risk

The second possible weakness was also initially identified as strength. CARE made great efforts to develop a very low cost technology to allow entry of the extreme poor. They were also at pains to ensure – in line with the livelihoods analysis paradigm – that the new activity in no way compromised or undermined existing livelihoods activities and strategies. Unfortunately, these apparent strengths may be associated with significant weaknesses. These requirements imply a part-time activity and in some cases a peripheral activity. Lack of investment and limited returns also imply an unimportant activity that can be readily neglected when other demands – whether they be social or economic – arise. And neglect of fish in cages is likely to lead to mortality, vandalism or theft. In other words, although low investment – of time and money – means you have less to lose; it may also mean that you are more likely to lose it. Lack of investment leads to lack of commitment, which in turn leads to lack of nurture, less rigorous guarding and finally greater likelihood of loss.

This contrasts with the situation in Viet Nam where a typical cage is 15–20 times the volume. The investment and demands of the fish are such that the family has no option but to live on the cages. Their life is transformed – this in no way "fits" with their previous livelihood activities – and they are committed to guarding and husbandry to protect their investment. Cooperation at a certain level also becomes essential to minimize risk. As a result, people make money and the technology spreads very rapidly. I have often asked poor people in Viet Nam why they did not start with smaller cages. The answer is usually simply that it is not worth it. If you are going to do it, you have to do it properly – full time – and generate a decent return. If you have to wait to raise the money, or work for someone else, so be it.

Labour

The opportunity cost labour of the very poor is often assumed to be very low – and certainly lower than standard agricultural rates. Development projects, in their assessment of financial viability of IGAs, often leave labour out altogether on the basis that it is free "family" labour. In practice no one is prepared to work for a very low financial return even on their own farm – they would rather relax (if they are not starving) or migrate (if they are). The case study of grass carp culture in cages in Dac Lak is instructive in this regard, and may also sound some warnings for very small cage culture using natural feeds in Bangladesh. Cage culture of grass carps in reservoirs had been very successful until disease struck. After several years, with disease no longer a major issue, various attempts were made to restart the culture, but with little success. Although fear of disease may have been a factor, the effort of collecting fresh green feed for the fish was also a factor, and employment opportunities in alternative activities had increased. A good return to labour is important – even for the poor.

Comparative advantage

If labour is charged at anything close to agricultural rates, small-scale cage aquaculture in Bangladesh, although still profitable, is nonetheless significantly less profitable than pond aquaculture (i.e. production costs are higher). Production from ponds is increasing rapidly, and this will ultimately result in downward pressure on price, which will affect cage culturists more severely than pond aquaculturists. In other words, poor people using small cages do not have a comparative advantage in the production of fish and ultimately they will suffer declining returns or go out of business. Unless they use initial success as a basis on which to develop and build more efficient enterprises they will remain poor. In this sense small-scale cage culture needs to be seen as a step on the development ladder rather than as a solution to poverty, and policies should recognize the dynamics of development.

CONCLUSION

Cage culture has great development potential, but we need to be careful about "designing it to fit in with livelihoods". It is costly to get the fit right, it is dangerous to get the fit wrong, and even if it fits in with livelihoods it may not be socially or financially sustainable. In the medium and long term very small-scale cage culture will not be competitive except in very special circumstances, although it may represent a very important stage in development – the bottom rung of the ladder. Intermediate- (family-) scale aquaculture is undoubtedly highly successful in many parts of Asia and can be competitive where an efficient distribution and marketing system is in place. In these circumstances the issue is not how to promote it, but how to manage it.

REFERENCES

Beveridge, M., Hambrey, J. & Bulcock, P. 2001. *The improved management of small-scale cage culture in Asia.* Final Technical Report, DFID Aquaculture Research Programme Project R7100.

Hambrey, J. 2002. Financial analysis and risk assessment of selected aquaculture and fishery activities in the Mekong Basin. *MRC Technical paper* No. 5, Mekong River Commission, Phnom Penh. 67 pp.

Hambrey, J., McAndrew, K. & Beveridge, M. 2001. Aquaculture and poverty alleviation 1: cage culture in freshwater in Bangladesh. *World Aquaculture*, 32(1): 50–58.

Hambrey, J., Tuan, L.A. & Thuong, T.K. 2001. Aquaculture and poverty alleviation 2: cage culture in coastal waters of Viet Nam. *World Aquaculture*, 32(2): 34–38

Hambrey, J. 2000. Global prospects for cage aquaculture of finfish: input costs, market value and comparative advantage. *In* I. C. Liao & C. K. Lin, eds. *Cage Aquaculture in Asia: Proceedings of the first international symposium on cage aquaculture in Asia*, pp 193–206. Manila, Asian Fisheries Society and Bangkok, World Aquaculture Society, Southeast Asian Chapter. 318 pp.

McAndrew, K.I., Little, D.C. & Beveridge, M. 2000. Entry points and low risk strategies appropriate for the resource poor to participate in cage aquaculture: experiences from CARE-CAGES project, Bangladesh. *In* I. C. Liao & C. K. Lin, eds. *Cage Aquaculture in Asia: Proceedings of the first international symposium on cage aquaculture in Asia*, pp 225–231. Manila, Asian Fisheries Society and Bangkok, World Aquaculture Society, Southeast Asian Chapter. 318 pp.

Tuan, L.A., Nho, N.T. & Hambrey, J. 2000. Status of cage mariculture in Viet Nam. *In* I. C. Liao & C. K. Lin, eds. C*age Aquaculture in Asia: Proceedings of the first international symposium on cage aquaculture in Asia*, pp 111–123. Manila, Asian Fisheries Society and Bangkok, World Aquaculture Society, Southeast Asian Chapter. 318 pp.

Finfish cage culture in Asia: an overview of status, lessons learned and future developments

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ABSTRACT

The paper provides an overview of cage culture in Asia, with an emphasis on farming of finfish in freshwater cages. Cage culture in all probability originated in Asia, with earliest records going back over 2000 years in China. "Traditional" systems, distinguished by reliance on natural construction materials such as wood and bamboo, collection of fish from the wild, and feeding on locally available resources, are still found in several countries in Asia. In the past few decades such traditional systems of holding have evolved into more "modern" cage farming, involving specially constructed cages, better designs and synthetic net materials, use of hatchery reared fry and fingerlings, various types of feeds, including formulated feeds and better organized management practices. Even though such modern systems are increasingly common, there is a diversity of cage farming systems found in Asia, covering a spectrum of traditional to modern systems, small to large-scale, with farming involving a very wide variety of species and environments, levels of input and risk. Small-scale farming enterprises still dominate the sector in many Asian countries though.

Cage culture has expanded in Asia because of a number of advantages, including the fact that cages make use of existing water bodies, and no land is required for farming (although land may be required for access to water bodies where cages are located). In many Asian countries, major inputs required for cage farming – feed, seed, materials, suitable water bodies, as well as technical support and markets – are available. Cages also provide opportunities for non-land owning sectors of the community to start fish farming, important in countries where fisheries are in decline, capitalizing on skills and supplementing income of fishers and people without easy access to land. In newly created water bodies, such as reservoirs, they have shown potential to provide an important means of fish production, and sometimes opportunities for alternative livelihoods for people displaced due to impounding. In economic terms, there may also be advantages

over land-based farms, although capital costs of investment in cages and inputs (seed and feed) may be a constraint to involvement of poor people. Marketing and economic aspects are key sustainability issues.

There are several examples in the region where cage farming was promoted without due attention to economics and marketing, leading to poor sustainability of projects. There are a number of disadvantages that need to be recognized as constraints to the development of cage farming. The key word is "vulnerability". Cages are "open systems", and therefore highly vulnerable to changes in the surrounding environment. They are vulnerable to water quality changes, for example resulting from water quality degradation (that in some cases may be caused by the cage farms themselves, or external events such as red tides), fish disease, damage from storms (particularly in coastal waters) and security problems such as poaching. Environmental constraints are therefore also key issues in the success and failure of cage farming.

The paper describes in detail the design and construction of cages, farming systems and practices, types of water bodies used for cage culture, major constraints, with an emphasis on environmental aspects, and provides recommendations concerning policy and legislation. Two detailed case studies involving common carp and tilapia farming from Indonesia and Malaysia, and one describing the recent history of river catfish farming in Viet Nam, are provided.

Background

This paper provides an overview of cage culture in Asia, with an emphasis on farming of finfish in freshwater cages, with some selected examples of cage farm development and lessons learned. Plates illustrating various cage farming systems are attached.

The information presented in the paper comes from a number of sources, including ongoing research of the Network of Aquaculture Centres in Asia-Pacific (NACA) and Deakin University and recent reviews of cage aquaculture (Liao and Lin, 2000; Beveridge, 2004).

Brief history of cage culture in the region

Cage culture, as in the case of most aquaculture practices, probably originated in Asia. Fishermen likely used the first cages and pens as a convenient holding facility for fish until ready for sale. The earliest systems may have been little more than modified fish traps. Such traditional systems have been used in several parts of Asia and elsewhere in the world for many generations (Beveridge, 2004). Such systems have gradually evolved to hold fish for longer periods with increasing levels of inputs, such as feeding of waste materials or "trash fish" collected from (usually) locally available capture fisheries as well as with better organized management and farming systems.

"Traditional" systems, distinguished by reliance on natural construction materials such as wood and bamboo, collection of seed stock from the wild and feeding on locally available materials, are still of common occurrence in several countries in Asia, e.g. in Cambodia for farming of snakeheads (*Ophicephalus* spp., *Channa* spp.) and river catfishes (*Pangasius* spp.). In marine environments, throughout much of tropical Southeast Asia, the farming of high value groupers (*Epinephelus* spp.) and other coral reef fishes, although using relatively modern cages, is still heavily dependent on the collection of wild fingerlings and juveniles, grown in cages for sale to the high value reef fish trade into Hong Kong and China.

In the past few decades such traditional systems have evolved into more "modern" cage farming, involving specially constructed cages, better designs and synthetic net materials, use of hatchery reared fry and fingerlings, various types of feeds, including formulated feeds and better organized management practices. Even though such modern systems are increasingly common, there is a diversity of cage farming systems found in

Asia, covering a spectrum of traditional to modern systems, with farming involving a very wide variety of species and environments, investments, inputs and risk.

Description of the current situation regarding cage culture in Southeast and East Asia

Cage culture production

In 2002, total world aquaculture production (including aquatic plants) was reported to be 51.4 million tonnes by volume and US$60.0 billion by value, of which Asia by volume contributed around 90 percent (FAO, 2004). It is not possible to determine the contribution of cage farming to the total volume and value in Asia. However, 80–90 percent of the estimated 1 million tonnes of marine fish cultured in Asia probably come from cage farming. In brackish water and freshwater the proportion is much lower, probably only a few percent of the total, with most farming being in ponds. Nevertheless in some countries and locations, cage farming provides an important source of fish production and income for farmers, other industry stakeholders and investors. In modern times cage culture is also seen as an alternative livelihood for example for persons displaced from the construction of reservoirs, the latter being an increasingly sensitive issue in most developing countries.

Advantages and disadvantages of cage culture

Cage culture has expanded in Asia because of a number of advantages compared with other forms of fish culture. One important advantage is that cages make use of existing waterbodies, thus being a non-consumptive user of water resources, which is of importance particularly with regard to freshwater, and requiring no land for farming (although land may be required for access to waterbodies where cages are located). In some cases, economics and quality of fish produced in cages can be considered to be better than pond reared fish, particularly in respect of organoleptic properties. This has driven development, such as in the case of river catfish in Viet Nam and common carp and tilapia in Indonesia and Malaysia. Cages also provide opportunities for non-land owning sectors of the community to engage in fish farming, being important in countries where fisheries are in decline, capitalizing on skills and supplementing income of fishers and people without easy access to land (Beveridge, 2004).

In human-constructed waterbodies such as reservoirs, cages have the potential to provide an important means of fish production, and sometimes offer opportunities for alternative livelihoods for people displaced during reservoir impoundment. In China, Indonesia and Malaysia, for example, cage culture has been successfully promoted in new reservoirs, as an alternative livelihood particularly for displaced indigenous communities. Also, in the wake of increasing demand for fingerlings of commonly cultured species in Asia, for pond culture and stock enhancement practices (De Silva, 2003), cages have been utilized in large lacustrine waterbodies for fry to fingerling rearing, thus reducing the demand for land-based facilities for such activities.

In economic terms, there may also be advantages over land-based farms, although capital costs of investment in cages and inputs (seed and feed) may be a constraint to involvement of poor people (Beveridge, 2004). In Bangladesh, for example, subsidies have proved necessary to allow poor rural farmers and fishers to start cage farming (Hambrey and Roy, 2002).

Marketing and the economics of cage farming are key factors influencing sustainability. There are numerous examples in the region where cage farming was promoted by projects without due attention to economic considerations and marketing strategies, thus leading to poor sustainability. Development of cage farming can also influence fish prices, also affecting other stakeholders. For example, large volumes of grass carp available in Ea Soup Reservoir (16 ha) in central Viet Nam led to significant depression of local fish prices, affecting income of fishers, particularly following a large cage fish kill (Phillips, 1998).

There are a number of disadvantages necessary to be recognized as constraints to the development of cage farming. As emphasized by Beveridge (2004), the key word is "vulnerability". Cages are "open systems", and therefore highly vulnerable to changes in the surrounding environment. They are vulnerable to water quality changes, for example resulting from water pollution (that in some cases may be caused by the cage farms themselves, or external events such as red tides or industrial effluent), fish diseases, damage from storms (particularly in coastal waters) and security problems such as poaching. Environmental constraints are therefore also a key to the success and failure of cage farming.

Cages in Asia are usually located in public or multiple-use waters, where expansion can lead to conflicts with other users. In south Korea, for example, the government banned freshwater cage farming in drinking-water reservoirs due to concerns over impacts on valuable freshwater supplies, leading to the closure of 221 cage farms and a loss of 30 000 tonnes of inland carp production (Kim, 2000). On the other hand, cage culture, without feed inputs, may be utilized to reduce eutrophication in potable water supplies, such as in the case of using Chinese major carps in Seletar Reservoir in Singapore, and for general bioremediation of potable water supplies. Uncontrolled expansion of cage farming in multiple-use waterbodies can also lead to conflicts with existing users such as fishers. The development of pen farming of milkfish in Laguna De Bay, Philippines, is one of the classic examples where the expansion of pen farming led to severe constraints to the access of fishers to traditional fishing grounds and to conflicts (Marte *et al.,* 2000); the Indonesian case study below also focuses on comparable conflicts.

Markets, economics, environment and social issues are therefore the keys to successful development of cage farming in the region and are given particular attention in this paper.

Cage farming systems

A wide range of cage farming systems characterizes the Asian region; a brief overview is provided below.

Cage design and construction. Cage structures should be cost-effective, but at the same time should provide a suitable environment for the farmed fish and be able to withstand the forces of wind and waves whilst holding the stock securely. Within Asia, a wide variety of cage and pen designs are found from small, traditional cages, to more modern types of construction. Although large-scale cages based on European or Japanese designs, such as the "Bridgestone" or "Polar circle" type cages, do exist and are adapted to Asian conditions, lower technology and traditional designs or construction techniques dominate in freshwater areas.

Traditional cages in freshwater utilize a variety of construction materials, such as wood or bamboo for frames, often using oil drums or other forms of flotation, together with various forms of netting. Simple anchoring systems are used, including ropes and block weights, or posts driven into the substrate. Some examples are provided below to illustrate the diversity of systems.

In Viet Nam, river catfish are cultured in large wooden or bamboo cages, made from "*sao*" wood and "iron" wood available in Cambodia and Viet Nam. The largest cage is 10 m wide, 25 m long and 5 m deep and produces 200 tonnes of catfish in six months (Plate 1). Such "heavy duty" cages, required because of the strong water currents in the Mekong River, effectively limit cage culture to people with access to significant capital to invest. At the other end of the scale are simple, non-floating cages, made of bamboo stakes, used in NamNgum Reservoir in Lao People's Democratic Republic, for culturing snakeheads *Channa* spp., and small wooden cages, under the houses in Cau River in northern Viet Nam, in which more often than not grass carp is cultured. It is also common to find a concentration of a large number of small-scale farmers as in the

Cau River in Viet Nam (Plate 2), possibly reflecting a traditional income earning means in places where a ready supply of cage building material as well as the required seed stock (often natural) are fairly easily available. On the other hand, small-scale individual cage culture activities are also often found when a ready source of natural fodder is available, for example grass/aquatic macrophytes for culturing grass carp, *Ctenopharyngodon idella* (Plate 3). In southern Thailand, seabass, *Lates calcarifer* are cultured in a brackish water lagoon (Songkhla Lake) using simple nets of 2–4 × 2–4 m, suspended from bamboos driven into the bottom of the lake (Plate 4). Such systems can also be found in other shallow lagoon areas in Asia where tidal and water level fluctuation is limited and there is reasonable shelter. They are simple and cheap to construct.

In freshwater reservoirs throughout Asia farming of carp, tilapia and other species is common within cages constructed of bamboo or wood, lashed to oil drums or other forms of flotation. An example is provided in Plate 5, from a reservoir in Viet Nam. This type of construction, with dimensions commonly from 2 m × 2 m × 2 m up to 7 m × 7 m × 7 m with nylon netting, can be found throughout Asian freshwaters.

Although in other regions there has been substantial investment in research to develop cage farming systems that conform mostly to fish behaviour, such research has been fairly limited in Asia to date. Research on improving the economics and management of cage farming systems in Asia, in most instances, will require increasing attention to improve performance.

Species and farming systems. Just as there is a wide range of cage farming systems in Asia, there is a wide range of farmed species and ways of farming. The most common freshwater species farmed in cages in Asia are tilapias (various strains of the Nile tilapia), carps, catfishes, snakeheads, gouramis, barbs and a host of minor species usually farmed intensively in freshwaters and seabass and groupers in brackish and sea waters. Both indigenous and exotic species are farmed in cages in Asia. Mostly, hatchery reared fish are used, although some systems (e.g. marble goby in Thailand, some river catfish, and snakehead farming throughout Southeast Asia) rely on wild caught fingerlings. One of the highest valued freshwater species, the Mandarin fish (*Siniperca chausti*) is cultured in cages in reservoirs in central China. This is important as the mandarin fish has to be fed with live fish; thus very often young cyprinids are cultured side by side to Mandarin fish in the same water body using much simpler and less robust cages.

Farming systems involve stocking of fingerlings, use of supplementary feed and management systems to optimize profits. Successful development requires ready access to suitable feed and seed in particular, but equally important are cage farming enterprise management skills.

Feeds represent a considerable investment in semi-intensive and intensive cage farming. In marine environments, and in some freshwater cage farming such as in catfish farming in Viet Nam, the heavy demand for "trash" fish is now being realized as a major constraint to future development of marine fish farming (Edwards *et al.*, 2004). In freshwater, supplementary feed is increasingly shifting towards pellets in more commercial operations, although home-made feeds are still widely used. Grass carp farming in Viet Nam, a profitable venture for many small-scale households in highland areas of the country, until struck by viral disease, was based on feeding of large quantities of grass (over 40 kg of grass required per kg of fish production!). River catfish production is also largely based on farm-made feeds, utilizing trash fish. Some freshwater carnivorous species are still cultured using fish collected from the wild, although there is increasing concern about the sustainability of this practice.

Extensive farming systems are also practiced with filter feeding fishes in waters where there is sufficient natural productivity to support growth. Examples of such systems can be found in Lao People's Democratic Republic, where filter feeding bighead carp and silver carp are farmed in productive reservoirs (Plate 6). In the Philippines, extensive farming of milkfish (*Chanos chanos*) was highly profitable in the 1980s but overexpansion of farming in Laguna De Bay led to significant over-cropping of natural productivity and to a near collapse of the industry. Changes in the natural productivity of the lake, a combination of pen farming and changes in the hydrology and ecology of the system, have led to changes in the way fish are farmed. Supplementary feeding of both milkfish and tilapias in pens has now replaced the extensive farming of milkfish to a large extent. Both, monoculture and polyculture can be found in cage culture in Asian freshwaters. Plate 6 from Lao People's Democratic Republic shows one example where two filter feeding fish are grown together – a zooplankton and phytoplankton feeder in an extensive system – and the feeding niche of one complementing the other. There are other examples of more intensive farming. In Indonesian reservoirs, for example, a double net system (locally referred to as "*lapis dua*") has evolved, with common carp growing in the inner cages, surrounded by tilapia in the outer cages (Plate 7). Tilapia are able to forage on waste feed, thereby at least, in theory, helping to reduce the losses of feed and thus reducing the impacts of waste feed on water quality and the surrounding environment. Vietnamese river catfish farmers commonly stock small numbers of barbs and other foraging fish to minimize feed wastage.

Freshwater cages are used for production of marketable fish, but also for nursing. Extensive development of small nursing cages – or "*hapas*" – for tilapia and barbs in Lao People's Democratic Republic and Thailand, sometimes in small reservoirs, irrigation canals or other small public waterbodies, has for example provided employment for small-scale operators (Plate 8).

Types of waterbodies. There are significant water resources available for cage farming in Asia, and there is a wide range of waterbodies used for freshwater cage culture. These include natural waterbodies such as lakes, lagoons and rivers as well as human-constructed waterbodies including large and small reservoirs, mining pools and irrigation canals, amongst others. Static and running waters are used. Cage farming provides the flexibility to exploit various types of water resources for fish production. A feature of many waters used for cage culture in Asia is that they are often multiple-use waterbodies. Thus, conflicts with other water users are a risk, and careful attention has to be paid to integration of farming with the other water uses. There are also other implications. In Indonesia, for example, government policy has focussed almost solely on promoting commercial cage farming in freshwater reservoirs of central Java, resulting in lost opportunities for the development of capture fisheries and negative impacts on small-scale fishers whose livelihoods depend on the capture fisheries and who cannot afford to invest in cages Abery *et al.,* 2005).

Selected case studies

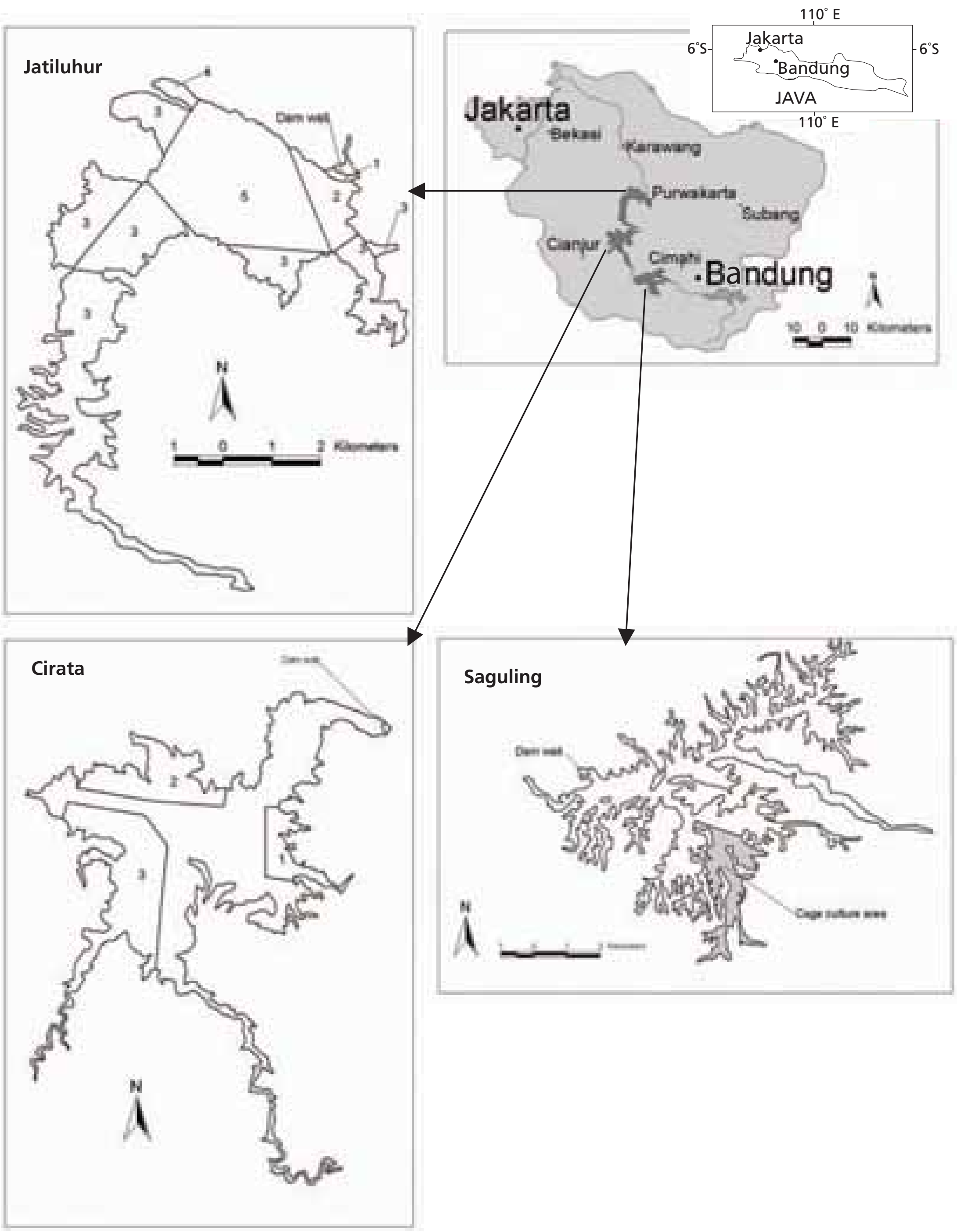
The following provides some selected examples of development of freshwater cage farming, to illustrate selected key issues concerning cage farming in Asia.

Indonesia – fish cage culture in reservoirs

Saguling, Cirata and Jatiluhur are located in the greater Citarum River watershed in central Java of Indonesia (Figure 1). Freshwater fish culture was promoted as a means of increasing fish production and providing livelihoods for people displaced from reservoir construction. Several studies have been conducted on these reservoirs, during the early stages following construction (Soemarwoto *et al.,* 1990) and more recently by De Silva *et al.* (2004), and Abery *et al.* (2005).

This case study, extracted from Abery *et al.* (2005), summarizes findings from these recent analyses, describing cage culture systems in the reservoirs, historical data on cage culture and fisheries of Saguling, Cirata and Jatiluhur reservoirs as well as lessons learned.

FIGURE 1
Locations of freshwater cage farming in Java, Indonesia



Cage systems and husbandry. In all reservoirs a two-net culture system is used, locally known as “lapis dua”. All cages are 7 × 7 m, with a bamboo frame (Plate 9); however, the depth of the outer cage differs between reservoirs and ranges from 5 to 7 m, depending on the location of the cages in the reservoir as well as on the reservoir’s depth and drawdown. For example, the mean depth of Cirata Reservoir is about 35 m and cages are located in areas of mean depth of about 60 m, and consequently in Cirata the outer cage is generally 7 m deep, while in Saguling it is only 5 m. The cage mesh size is 1.5 cm and five or six ply netting is used, with each net having a life span of three to four years. The inner cage is often 7 × 7 × 3 m and is used for common carp culture *Cyprinus carpio*. As a rule, the outer cage is stocked with Nile tilapia (*Oreochromis niloticus*). Mean stocking size is about 7 to 8 cm, and on average each cage is stocked with about 100 kg fingerlings each of common carp and Nile tilapia.

Most cage operations manage two growth cycles per year. Nile tilapia and common carp are harvested at individual weights of about 330 to 500 g (2–3 fish per kg) and of 250 g, respectively; the current farmgate price is INS Rp4 000 and 6 000 per kg (8 500 INS Rp = 1 US$), respectively. Pellet feed is provided only for the common carp stocked in the inner cage, and most feeds (pelleted, commercial feeds, obtained from varying suppliers) contain about 11 to 13 percent moisture, 26–28 percent protein, 6 to 8 percent lipid and 4 to 6 percent ash and fibre. The price of feed of the various brands ranged from INS Rp2 420 to 2 900 per kg. Fish are fed a number of times a day, amounting to approximately 10 to 12 percent of the body weight per day. Most farmers report that the mean food conversion ratio (amount of dry feed input/increase in wet biomass), for both species, ranges from 1.2 to 1.3.

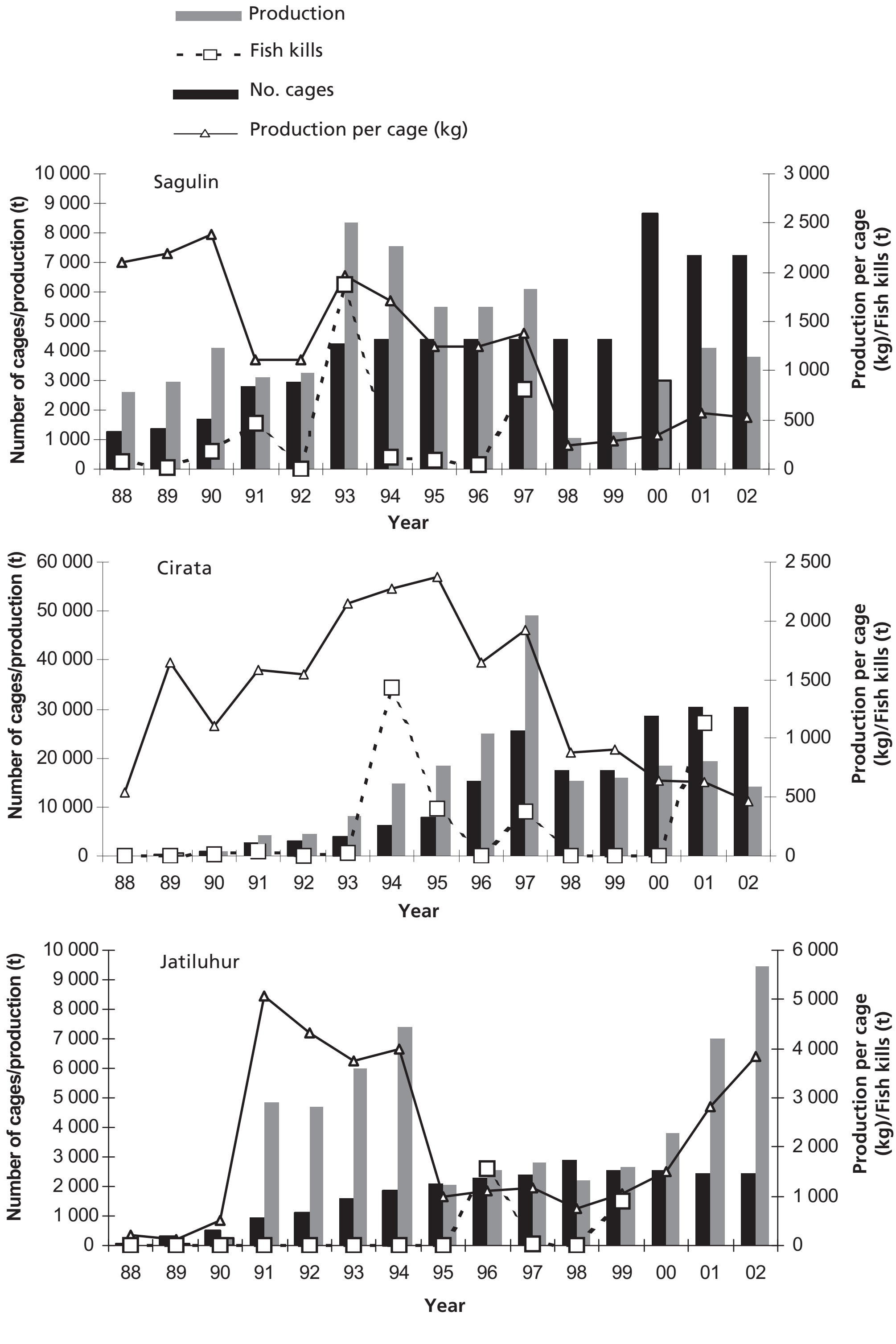
Cage fish production. The number of cages in each of the reservoirs has increased dramatically over the last 14 years, except in Jatiluhur, which has stabilized at around 2 000 cages, as opposed to about 7 000 and 3 000 in Saguling and Cirata, respectively. In all three reservoirs the increased number of cages resulted in significant increases in fish production. Cage fish production peaked in 1993, 1994, 1997 and 2000 in Saguling, Cirata and Jatiluhur, and was soon followed by decreases, except in the case of Jatiluhur which has witnessed an increase in production in the last three years. However, the fish production per cage has declined dramatically (Figure 2); in Saguling from 2 200 kg in 1989 to less than 500 kg per cage in 2002 and in Cirata from a peak of about 2 300 kg in 1995 to about 400 kg per cage in 2002. In Jatiluhur, however, total fish production and production per cage has increased since 2000, and the latter (about 4 000 kg per cage) is close to the level in the early years of cage culture activities.

Increasing fish kills. Cage fish kills first occurred in Saguling (72 tonnes) in 1988, followed by Cirata (10 tonnes) in 1990 and in Jatiluhur (1 560 tonnes) in 1996. After the initial occurrences, fish kills tended to occur in a somewhat irregular fashion in all three reservoirs. Fish kills were variable through the years and did not increase proportionately to the production level. However, fish kills were typically absent during very low levels of production such as that in the earlier years in the Cirata and Jatiluhur reservoirs (Figure 2).

Reasons for the decline and reduced returns per cage relate to a deterioration in water quality and the introduction of a new fish virus – Koi herpes virus (KHV) – that significantly impacted on production. Nutrient loadings from cage culture operations have certainly further contributed to the problems.

Fish kills are particularly associated with cooler weather or rain, leading to upwelling of bottom water. Under normal conditions when reservoir levels are high stratification occurs and generally only the cooler bottom layer remains anoxic and consequently wild fish are unaffected as they often tend to inhabit the upper reaches of the water column. In conditions of low reservoir water levels or changing weather conditions mixing can occur and cause the anoxic conditions to occur throughout the water column along with high concentrations of toxic substances such as NH_3–N, NO_2–N and H_2S. The upwelling, which to farmers is a well-known phenomenon, results in fish

FIGURE 2
Trends in fish cage production in three Indonesian reservoirs (from Abery *et al.*, 2005).



kills of both cage fish and wild fish stocks. Farmers are now aware of the risk periods, and may market fish before high risk periods, but still disease and fish kills impact on profitability.

Nitrogen and phosphorous loadings. Studies of nutrient loadings and sedimentation models show that the cage culture operations in all of the reservoirs are responsible for large inputs of nutrients. Portions of these nutrients are dissolved and some accumulate in the sediments (although there is still uncertainty about the amount that actually reaches sediments and the amount of waste foraged by wild fish). Organic material accumulates on the bottom of the reservoir under cages and can create considerable oxygen demand in already low oxygen conditions.

Generally, cages are located in localized areas (bays) in the reservoirs and are often in an overcrowded state (Plate 10). Hydrological conditions in secluded bays do not permit effective water exchange and lead to higher nutrient accumulation in those areas, particularly in the sediments. The appropriate siting of cages and the reduction of densities within areas of better water exchange may be a possible solution to minimize fish kills. Saguling also receives a considerable quantity of domestic and industrial effluent from the city of Bandung with an estimated population of 2 million people, further contributing to water quality and fish kills in this reservoir. Cage operators live in accommodation on the cage sites, contributing some additional nutrient and organic loadings to the waterbodies.

Wild fish and fishers. By far the main species caught in all three reservoirs are various tilapia species followed by common carp. The wild fish production in the three reservoirs has generally increased over the last ten years, probably because of escapes from the cages. There is evidence of reduction in wild fish catches in Jatiluhur reservoir which showed large declines in catch in 1996, 1997 and 1999 when fish kills were observed. Thus, there are negative and positive aspects to the livelihood of fishers from development of cage farming in the reservoirs. Preliminary studies suggest that an integrated approach to fish production in the reservoir – considering both the management of cage farming and capture fisheries – could improve overall fish production and socio-economic benefits from the reservoir.

Management systems. Overall management authorities for the three reservoirs are different; the fishery aspects are managed and monitored by District Fishery Authorities, which are under the Provincial Government. In the case of Cirata reservoir the fishery aspects fall under the jurisdiction of three district authorities: Bandung, Purwarkarta and Cianjur. The District Fishery Authorities have the responsibility for issuing cage culture licenses, monitoring and collecting production data and also for monitoring the fishery. In the case of Saguling, there is no licensing system in operation and an open access policy is maintained, probably contributing to overproliferation of cages and ultimately fish kills in this reservoir.

In all reservoirs the cage culture sites and the number of licenses to be issued have been predetermined. However, over the years cage culture activities have intensified through a larger number of units being used by individual farmers, adoption of two-net culture systems, increased stocking density and feeding rates, resulting in the general trend towards overstocking. The most successful management systems are in Jatiluhur, where there are clearer management responsibilities and a zoning system agreed by the stakeholders.

Lessons learned. The main lessons from this case are: (a) increasing nutrient loading in the reservoirs, a combination of overstocking and poor location of cages have led to a deterioration of water quality influencing cage fish and profitability of farming; (b) wild fishers have been impacted by cage farming development; it is needed now to move the reservoirs towards integrated management, seeking optimal benefits for both the fishers and farmers and to sustain both activities harmoniously; (c) an effective licensing system related to the nutrient and organic load, and better farm management are required to limit the fish production within designated zones in the reservoirs. Further research will be required to determine optimal carrying capacity. It will be necessary to move consensus among local stakeholders towards joint local management agreements and clear responsibilities.

Viet Nam – catfish cage culture in the Mekong River

The Mekong River delta is a major region for fishery and aquaculture production in Viet Nam, with total aquaculture production of 740 000 tonnes in 2003, or nearly 70 percent of the country's total aquaculture output. Farming of river catfish is an important freshwater aquaculture activity in the Mekong region with fish reared in floating cages, pens and ponds. "*Tra*" (*Pangasius hypophthalmus*[1]) and "*basa*" (*Pangasius bocourti*) farming is a traditional occupation for many farmers in the Mekong Delta (Trong *et al.*, 2002) (Plate 11). Since the government's trade liberalization reforms in the late 1980s, catfish production has increased substantially, driven by increasing organized production and marketing systems as well as export sales. Production reached 120 000 tonnes in 2003 and was still expanding in 2004 (Nguyen and Phillips 2004).

This case study provides the example of a river-based cage farming system, an analysis of the livelihoods of people involved and market constraints faced by Viet Nam in this development. The description is based mainly on Nguyen and Phillips (2004) and Phillips (2002).

Farming systems and husbandry. In 2003, there were more than 5 000 fish cages in four Mekong Delta provinces. Cages range from 50 to 400 m^3 in size, with larger cages commonly consisting of living quarters on top and the submerged cage portion below (see Plate 1). River catfish, snakehead, red-tail tin foil barb (*Barbodes altus*), silver barb and common carp are most often reared in cages, stocked with one major species, plus a few common carp to utilise uneaten feed. For river catfish and snakehead, stocking densities for nursing and growout are 200–300 and 80–150 fish/m^3, respectively, at a size of 5–6 g. Other species are stocked at 80–100 fish/m^3. The main farmed species in the region is river catfish, driven by the significant demand for export product. The "*basa*" species is more valuable, but production is constrained by availability of seed. "*Tra*" is dominant, with fish from cages generally perceived to have higher quality for processing, and consequently a better price than fish reared in ponds. Figure 3 shows some recent price trends and interesting differences between the species and culture systems. Consequently, there has been considerable investment in cage farming in the Mekong Delta.

In cages, river catfish are fed wet sticky balls, prepared on farm, of mixed rice bran, broken rice and trash fish. Some formulated diets are available, but farmers prefer feeds they prepare on site– farm-made feeds – because of tradition and price. Vegetables were previously used for river catfish, but are no longer used as ingredients as they contain carotenoids, which caused the flesh of the now dominant species, *P. hypophthalmus*, to turn yellow and be rejected by fillet processing plants. Catfish are cultured for between 10–14 months and yields are very high, ranging from 80–120 kg/m^3. Cage culture of high value species requires investment levels beyond the reach of poor and marginal farmers. However, there are significant numbers of poorer people involved in the industry, as labourers and processing factor workers.

[1] The species is also referred to as *Pangasianodon hypophthalmus* – Van Zalinge *et al.* (2002).

Fish production is heavily dependent on the supply of low value “trash” fish, from wild fisheries in Viet Nam and Cambodia, both freshwater and increasingly marine sources. Using trash fish as feed transforms a low economic value product into a higher value product – the cage reared fish – but concerns have been raised whether expanding demand impacts on the environment and the availability of fish for poorer consumers. Edwards *et al.* (2004) noted that the demand for low value fish for catfish feed has contributed to increased prices of trash fish, expressing concern about the impacts on poorer consumers who rely on low value fish for food.

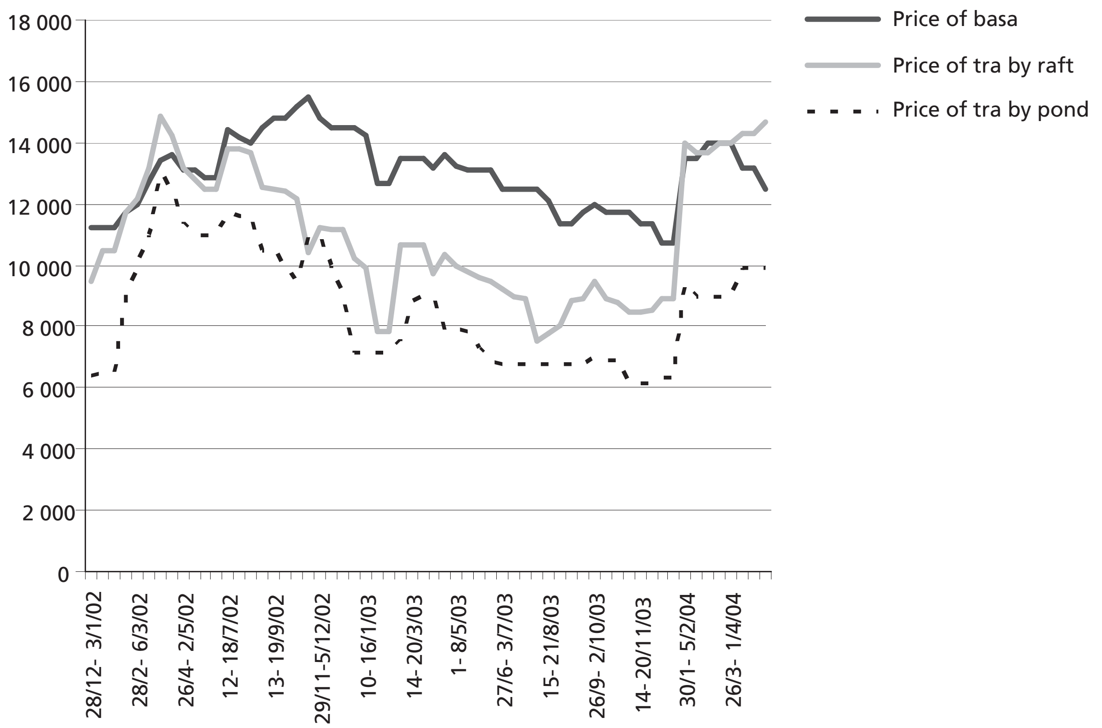
Environmental issues also relate to the impact of wastes from cage farming on river water quality and fish disease problems. Studies of waste discharge suggest that the fast flow of the Mekong River reduces environmental impacts. Nevertheless, water quality is reported by farmers to be a particular problem during the dry season at low water flows and a concern also when rice farmers discharge water containing pesticides and fertilizers from their rice fields. Disease outbreaks in river catfish also occur at such times.

Diversity of stakeholders. Although the levels of investment in cage farming are beyond the reach of poor people in the Mekong Delta, this highly commercial industry supports a large number and diversity of people and is a substantial employer. In 2003, cages and ponds together provided employment for over 11 000 households and an estimated 30 000 poor landless people who worked as labourers, particularly in feeding, in the two major farming provinces near to the Cambodian border (Nguyen and Phillips, 2004). In 2003, there were also over 8 000 people working in fish processing factories, processing catfish fillets for export. Poor women make up a particularly high proportion of over 70 percent of workers in the processing factors. Several thousand people are also involved in provision of services (finance and credit, fish feed and fish seed, traders, veterinary services, storing and transportation) for the catfish farming industry.

Marketing vulnerability. The Vietnamese catfish industry has developed successfully, based on increasing market demand and production of a competitive product. Recent history shows that the industry, and the people involved, are vulnerable to international market changes.

The success of the industry and growing exports to the United States of America in particular led to a well known “anti-dumping” case against Viet Nam. In June 2002, the International Trade Commission (ITC) of the United States Department of Commerce (DOC) received a petition from the United States Catfish Farmers Association and eight individual catfish processors in the United States demanding an anti-dumping investigation into the imports of certain Vietnamese frozen fish fillets. The petitioners alleged that the Vietnamese frozen fish fillets were sold in the United States at less than its production value and that the imports were damaging the United States’ domestic catfish industry. After its investigation in January 2003, the Department of Commerce ruled in favour of the United States’ catfish industry, and levied a series of tariffs against Viet Nam’s catfish exporters from 37 to 53 percent. This decision led to significant impacts on the stakeholders involved in the industry. The most immediate effect was a decline in the farmgate price of *basa* from VND14 000 to prices around production costs of around VND7 000 (see Figure 3). Farmers, farmer associations, processing factories and government took various actions including: (a) cost cutting, particularly by the farmers and processing enterprises, leading to loss of employment among poorer people working as labourers or as processing factory workers; (b) promotion of domestic consumption, through marketing campaigns, leading to a significantly increased consumption of catfish in Viet Nam and to reduced immediate dependence on export markets. This domestic consumption campaign fortunately (for the catfish farmers) coincided with an outbreak of avian flu when demand for fish products

FIGURE 3
Prices of "basa" and "tra" catfish in the Mekong Delta



increased; (c) diversification of international markets and products, helping to reduce dependence on the Unites States market, and opening new markets in Asia and Europe for more diversified catfish products; and (d) further investment in quality control measures to assure new markets of product quality.

These concerted efforts by the industry and government actions were successful. After a decline during 2003, catfish cage farming in the Mekong delta has bounced back considerably in 2004 and reached record levels of production and export, but the emphasis is changing from cage to pond culture (Hung, Le Tanh, pers. comm.).

Lessons learned. The Viet Nam case shows the development of a successful commercial cage industry based on river catfish, but also the vulnerability of this industry to international market changes. Although many farmers and processing business are above the lowest socio-economic strata, the industry had successfully employed significant numbers of poor people in an area with significant numbers of poor people. Market changes led to impacts on some of the poorest groups. Vulnerability was made worse by the absence of strong social protection policies ("safety nets").

Lessons learned from this case are: (a) cage farming of river catfish in Viet Nam was and is a profitable business, producing product of better quality than ponds because of the running water systems employed; (b) the development of a successful cage farming industry has generated significant benefits for a wide range of stakeholders; (c) to compete in international markets, Vietnamese businesses have had to invest considerably in implementing sanitary standards and quality control; (d) although studies have shown that cage culture does not significantly impact on water quality, because of the fast flowing nature of the river, environmental constraints caused by water quality changes and diseases are important; zoning regulations and restrictions of the number of cages by government have helped to minimize impacts, and will be essential to sustain the industry; (e) the success of the development has been related to the development of management systems, policy support as well as research and development support, from both local and central government, and increasingly well organized marketing and quality assurance systems.

Malaysia – red tilapia cage culture in Sarawak

With the impounding of BatanAi Reservoir (8 400 ha) in Sarawak, East Malaysia, in 1984, thousands of people were displaced. They were mostly belonging to the ethnic minorities, living in the valley and their livelihoods were dependent on agriculture. A proportion of these displaced persons/families was given the option of cage culture as an alternative livelihood; accordingly a cooperative was formed to manage the activities, and the Government of Sarawak provided subsidies for installing the cages. Concurrently, a hatchery was also built, below the dam, with a view to producing the required seed stock for the cage farming operations. Red tilapia was decided to be the best suited species, and to date all operations are based on red tilapia.

In the early stages 3 × 3 m cages were set up for groups of families, in units of 70 to 80 cages, in total 16 such units for the whole reservoir were set up. Each family owned two cages of each of the larger units. For example, the Area Farmer Organization Cooperative, with a membership of about 1 000 farmers, has 323 cages. The responsibility of feeding, keeping watch and general husbanding was taken in turns by each family. This community farming trend still continues to a certain degree, but on the other hand, some cage units are now singly owned. A number of such large units may form a cooperative to deal with feed purchasing and marketing. However, now a large private farm operates 304 cages, and a smaller one operates only 20 cages.

The average size of red tilapia at time of stocking is 80 g; each cage is stocked with about 500 fish. Often a monthly stocking and harvesting programme is maintained, on each occasion 15–20 cages being harvested at any one time, approximately six to seven months after stocking, the average size of fish being 500 to 600 g. In general, there is a recovery of 70 to 80 percent of the stocked seed. The stock is almost always fed a commercial pelleted feed, often ranging in protein content of 28 to 32 percent by dry weight, costing about 2.72 Malaysian ringgit per kg (3.5 Malaysian ringgit=1 US$).

The average cost of production is about 4.30 ringgit per kg, and the farmgate price is 6.0 ringgit per kg. On the other hand, the price for the consumer is about 30 ringgit per kg. The disturbing fact is that small farmers are finding it increasingly difficult to make a reasonable profit to maintain their livelihoods. With increasing feed costs and the fixed farmgate price, which has been prevalent for over four years now, the overall sustainability of cage farming of red tilapia may be at a risk, unless urgent measures are taken, either to make available a lower cost feed or to increase the farmgate price. Currently, in BatanAi Reservoir there does not appear to be overt environmental degradation resulting from cage farming. This is thought to be resulting from the reasonable density of cages in the reservoir, and also because the cages are located in proximity to the dam, where water is relatively deep with higher flushing rate.

MAJOR CONSTRAINTS CONFRONTING CAGE CULTURE IN ASIA

Freshwater cage culture is growing in popularity in Asia, probably also getting more intensive and contributing increasingly to fish production in the region. Experiences during this development in Asia reveal a number of significant issues as outlined below.

Technical aspects

These include issues related to cage design, construction, farming systems and management practices. Major technical issues relate to the quality and availability of fish seed, availability of suitable cost-effective feeds as well as the development and operation of cost-effective cage systems. In freshwater environments, cost-effectiveness of cage investments is a major factor, due to the relative low market price of most species produced.

Social aspects

The development of cage culture has provided opportunities for non-land owning sectors of the community to engage in fish farming, for market production or nursing. For the poorest fishers and farmers, considerable assistance and subsidies may be required to engage in small-scale cage culture (Hambrey and Roy, 2002). Cage farming usually takes place in public waterbodies, creating potential for social conflict if not well planed and managed. Care is therefore needed in the planning stages, with effective consultation, to avoid negative social impacts. Equity issues are also important.

Economics and markets

Economic and market issues are clearly important, both in terms of the investment required (and ability of different social groups to participate), profitability of farming and risks associated with investments in cage farming. The ability to compete in international markets, the need to be aware of and manage market risks are important issues affecting the successful development of cage farming in the region. The development of local markets is an option to help reduce the exposure to international risks.

Table 1 summarizes costs and returns from tilapia monoculture in cages (100 m^2) in selected Asian countries. All values are in US$ per unit cage area (from Dey and Paraguas, 2001); the data have been converted to 1999 prices using country-specific wholesale price indices in US dollars. The table shows the Chinese cage operations providing substantially higher returns per production cycle, although cage culture operations in Indonesia and Thailand are, on the average, more cost effective than those in the other two countries. Cage operators in Philippines spend on average US$0.43 per kg while in China they spend US$1.30 per kg.

Table 2 shows the share of variable costs of the different inputs in tilapia cage culture in selected Asian countries (also modified after Dey and Paraguas, 2001).

In all countries, feed is the highest cost factor, in Thailand being excessively high with 87 percent of total variable costs. These data have been further analysed with respect to:

- comparative advantage: the economic advantage for a country to expand production and trade in the commodity;
- competitive advantage: whether a country can successfully compete in trading the commodity in the international markets.

Both parameters were calculated using the domestic resource cost (DRC). The DRC is the quantum of domestic resources that a country uses to earn (through

TABLE 1
Costs and returns from tilapia monoculture in cages (1999) (modified after Dey and Paraguas, 2001). All values are in US$ per unit cage area

Parameter	China	Indonesia	Philippines	Thailand
Gross returns	10 724	756	649	428
Variable costs	6 181	280	297	350
Fixed costs	1 132	57	165	10
Total costs	7 313	337	462	359
Return over variable costs	4 543	476	352	78
Net return	3 411	419	187	68

TABLE 2
Costs and inputs (in %) in tilapia cage cultures of selected Asian countries (modified after Dey and Paraguas, 2001 – note that the values for Philippines and Thailand do not add up to 100%)

Parameter	China	Indonesia	Philippines	Thailand
Stock	38.0	43.9	27.1	10.8
Feed	54.3	44.8	53.2	86.5
Labour	3.1	9.4	17.1	7.2
Hired	0.9	9.4	8.9	4.3
Family	2.2	-	8.2	2.9
Others	4.6	1.9	0.2	-
Total	**100**	**100**	**97.6**	**104.5**

export) or save (through import substitution) for one unit of net foreign exchange in the production of the commodity (Medalla, 1983). Table 3 shows the competitive and comparative advantage of tilapia cage culture in selected Asian countries.

The average price of frozen tilapia in the United States of America in 1999 was used as the border price (US$1.24/kg) for all countries, after adjusting for freight and insurance.

The analysis shows that all countries have a comparative advantage in cage culture of tilapia, except China. When market distortions are taken into account only operations in Indonesia and Thailand can successfully compete with other countries in exporting tilapia to the United States. The Philippines are unable to compete because of distortions in the domestic market (neutral competitive advantage). China requires a border price of at least US$1.18 and US$1.43 per kg to maintain its comparative and competitive advantage, respectively; conversely it should yield 7 000/kg/m^2 and 7 780/kg/m^2 given a border price of US$0.94 and an Official Exchange Rate (OER) of Ch¥ 8.28/US$ to sustain the comparative and competitive advantage, respectively (Dey & Paraguas, 2001).

Ecological and environmental issues

Environmental issues are particularly significant and likely to become more so in the future, as pressures on freshwater resources increase. The major reason is that cages and pens are "open" systems and interact with the surrounding environment and other resource users. Cages can be risky and vulnerable with respect to:

- impacts on cage culture – water pollution, water flow, depth fluctuations, predators, poaching and the risks caused by "external" environmental change;
- "self-pollution" from release of nutrients and organic matter – sediments, water quality and disease, leading to sustainability problems;
- risks of creating environmental problems for other users – such as loss of visual amenity, impacting on navigation and small fishers; and
- potential impacts on wild fish stocks, e.g. through escapes, exotics, disease transmission and locating cages on spawning grounds.
- "draining" local resources that may impact on others – such as feed for carnivorous fish, grass for grass carp and construction materials (forests!).

The development of effective environmental management systems is therefore one important issue influencing the future development of cage farming in Asia.

Government policy and legal support

Government policy, institutional and legal support has been important contributing factors to the development of cage farming in Asia. Whilst the development in many cases has proceeded without significant micro level government intervention, often resulting in uncontrolled expansion, governments in most countries have provided positive policy support to the development of aquaculture, and technical support, allowing the development of cage farming to proceed. The next section discusses some of these aspects as well as the monitoring and regulatory framework seeming

TABLE 3
Competitive and comparative advantage of tilapia cage culture in selected Asian countries (modified after Dey and Paraguas, 2001)

Parameter	China	Indonesia	Philippines	Thailand
Average indicative prices (US$ kg^{-1})	0.94	0.40	0.94	0.94
Yield (Live weight equivalent in kg)[a]	5 613	789	540	780
Frozen yield equivalent (kg)	5 103	717	491	709
Economic analysis				
Domestic cost (local currency)	36 322	1 922 204	14 121	6 069
Foreign cost (local currency)	17 129	699 959	4 563	8 463
Total cost	53 542	2 622 163	18 685	14 532
DRC[b] (using 1999 border price)	12.64	3 193.13	38.1	12.8
SER	8.91	9 744.9	50.5	43.9
RCR[d]	1.42	0.33	0.75	0.29
Financial analysis				
Domestic cost (local currency)	40 201	2 209 177	16 144	6 069
Foreign cost (local currency)	19 033	777 733	5070	8 463
Total cost	59 234	2 986 910	21 214	14 532
DRCb (using 1999 border price)	16.43	376 981	45.99	13.35
OERc	8.10	8 859	45.99	39.95
RCRd	2.03	0.43	1.00	0.33

[a] reported yield ÷ 1.1
[b] Domestic resource cost
[c] Official exchange rate
[d] Relative cost of reuse

appropriate under Asian conditions, with an emphasis on environmental aspects. The Code of Conduct for Responsible Fisheries (FAO, 1995) can also be referred to for guidance on key issues to be considered in development of cage farming, and general responsibilities of states and the farming sector for responsible development.

Environmental considerations in cage culture

Siting and choice of waterbody

The choice of site for cage farming greatly influences the likely success of the farm, environmental risks and social interactions. Key issues include:

- Selection of sites that are environmentally suitable with respect to the species farmed (such as temperature, dissolved oxygen, natural food availability for extensive farming) and farming system (e.g. water depth, shelter).
- Selection of sites that reduce risks of environmental change caused by other activities (e.g. industrial, rural pollution) or impacts of natural events, such as harmful algal blooms, on cage farming investments.
- Selection of sites that reduce impacts of cage farming on water quality, key aquatic habitats and other water users.
- Selection of sites in lacustrine waterbodies, lakes and reservoirs, in the upstream areas where the nursery grounds of most indigenous species generally tend to be found, and also where access to the upper catchments of these waterbodies become relatively easily accessible.

Addressing such issues requires management actions by both government and the industry/farming sector.

Governments can take responsibility for regulating developments through establishing a licensing of permitting systems, or establishing zones where cage farming is allowed. Most successful systems tend to be where local government is actively involved in developing the permitting or zoning regulations, or where management agreements have been developed jointly by local farmers and local government (co-management). In Chinese reservoirs, for example, strong local regulations have allowed zoning of areas for cage culture, helping to optimize production from cage farming and capture fisheries

BOX 1

Recommended establishment of cage aquaculture zones in a freshwater reservoir (after Phillips, 1998)

Step 1: Identify zone
Activities: Resource surveys, particularly to identify suitable areas and uses; identification of reservoir stakeholders; consultations with reservoir stakeholders (communities, government); identification and delineation of suitable zones.
Issues: Suitable depths, carrying capacity, presence or absence of important fish habitats, spawning areas, current uses. Zone should provide for adequate spacing of cages. Consultation and agreement among reservoir stakeholders is essential. Discussions on zoning should be within the context of overall reservoir fisheries management and uses.

Step 2: Establish user group
Activities: Consultations among stakeholders to establish group.
Issues: Attention should be given to ensuring participation of target groups. Zoning system could be used to designate rights to certain groups and users. Equity issues need careful consideration.

Step 3: Zonal management system agreed
Activities: Management system developed among users group; institutional support requirements identified; training/capacity building of users groups and supporting institutions; management activities and responsibilities identified, e.g. security, marketing, nursing, etc.

Step 4: Zone legally established
Activities: Zone location, users group and management system should be agreed by local government.
Issues: Exact nature of the legal status should be discussed with users group and local government as part of the consultation process above.
Incentives/disincentives can be looked into. Permitting system agreed.

(Wu *et al.*, 2000). Plate 12 shows an aerial photo from Hong Kong, where (in marine waters) government has designated special areas for cage farming, within estimated carrying capacity, to reduce impacts of cage farming and interactions with other coastal users. Environmental monitoring is conducted to determine the continued environmental suitability of zones for farming. An example of process for zoning, developed for a freshwater reservoir in Viet Nam (Phillips, 1998), is provided in Box 1.

In some cases, Asian governments have taken decisions to restrict cage farming in certain waterbodies. In South Korea, a government policy decision was made to ban freshwater carp farming in drinking-water reservoirs, because of concerns regarding impacts of farming on water quality (Kim, 2000). Pens have also been removed from parts of Tai Hu, a lake in Jiangsu Province, China, due to concerns over impacts on water quality and amenity.

Considerable opportunities exist for farm level design and operational decisions to improve environmental management of cage culture. Choice of cage type and mooring, distribution of cages, getting the right cage design for the location (e.g. river cages not in reservoirs) all play a significant role for the economic success of the cage farm and they influence its environmental performance. Government can assist in providing technical support through extension support and training.

Waste control and effluent management

The environmental sustainability of cage and pen culture is closely related to the capacity of the environment to:

- absorb waste materials without adversely affecting water quality, or otherwise impairing the long-term capacity of the lake/reservoir/waterbody to absorb waste materials;
- supply inputs necessary to sustain culture: in more "intensive" forms of cage/pen aquaculture, the main concern is dissolved oxygen; in more extensive forms of culture, natural productivity is required, e.g. plankton for filter feeding fish.

Waste material from cages including nutrients, organic matter, solid wastes and other materials (either directly from fish culture or from associated activities such as humans living on cages) can lead to significant deterioration in water quality and sediments. The extent of this impact will depend on various characteristics of the farm and its location (hydrology, production levels, farm management practices and others). In general, extensive cage farms are net consumers of primary productivity and nutrients from a waterbody while intensive farms are net producers. Semi-intensive farming can either stimulate or reduce nutrient levels and productivity (Beveridge, 2004).

At local levels, such problems can impact on water quality and farming success. More significantly, such problems may impact on the overall quality of a waterbody as well as on its values and use for other aquaculture farms and other users. From the region, there are several examples of consequences of intensive (e.g. carp farming in Indonesia reservoirs, grass carp farming in Viet Nam) and extensive cage farming (e.g. Laguna De Bay in the Philippines). Key issues include:

- Keeping levels of fish production and waste discharge within the assimilative capacity of the environment (both, locally and within waterbody as a whole).
- Reducing wastes to the environment through efficient use of feed and other management practices.

Much research has focused on investigating waste discharge from temperate cage farming and on the development of predictive models for assessing environmental impacts (for a detailed review see Beveridge, 1994), but only limited practical work has been conducted in Asia. Governments in Asia have generally not adopted assimilative capacity assessments as part of the regulatory frameworks, probably because of the complexities and costs involved, although there is interest (e.g. Indonesia) for doing so. Box 2 gives examples of factors important in determining assimilative capacity for intensive cage culture, based on an assessment of carp farming in a highland reservoir in Viet Nam (Phillips, 1998).

Considerable opportunities also exist to improve environmental management at the farm level. Sitting and management of cages in reservoirs play a significant role in the environmental impact of cage culture. Box 3, also derived from experiences in highland reservoirs in Viet Nam, identifies some options for maintaining environmental quality in a reservoir used for intensive cage culture.

Environmental monitoring can (and should) be used to determine the impacts of cage farm development on waterbodies, to assess actual changes following development as well as to help modify assimilative/carrying capacity calculations and management practices. Environmental monitoring might include such factors as: (a) nutrient status (N and P); (b) chlorophyll measurements to assess effects on phytoplankton; (c) dissolved oxygen measurements (inside and outside of cages, surface and bottom measurements) (weekly/monthly at selected sites, including potentially anoxic areas); (d) Secchi disc depths (ideally on a daily basis as part of farm management to determine gross water quality changes); (e) temperature (weekly, again as part of farm management) and (f) developing nutrient budgets for the farm (inputs and output of phosphorus and nitrogen).

BOX 2

Factors used to determine assimilative capacity in a highland reservoir in Viet Nam used for grass carp cage culture (modified from Phillips, 1998)

- Water inflow: More water means greater dilution of wastes (faecal mater, nutrients, dissolved organics) and less risk of water quality deterioration. Water inflow is related to the watershed area (and land-use type), rainfall amount and seasonal patterns.
- Reservoir volume: Larger reservoir volume (mean depth versus area) allows for greater capacity of the reservoir to absorb wastes. Larger water volume in the dry season also improves assimilative capacity of the reservoir environment at critical times.
- Cage culture production: The production volume will determine the amount of waste material produced, particularly the volume of organic material and nutrients. Management factors and site location also play an important role in waste discharged for a given production level, as may seasonal factors.
- Water quality and existing water uses: Existing water quality determines the suitability of a reservoir for cage culture, and also its capacity to absorb additional nutrients and organic material. Existing water use will also determine to what extent changes in water quality are acceptable (e.g. changes in water quality might not be acceptable in a drinking-water reservoir, but be more acceptable in an irrigation water reservoir for agriculture). In many freshwater environments, phosphorus concentrations are used as an indicator of the trophic status of the waterbody.

Species selection and aquatic animal movements

Markets are obviously a critical factor in the selection of species, however, there are environmental issues concerning the choice of species. Key issues include:

- the suitability to the local environment and required inputs (e.g. does the species feed low or high in the food chain, can it be farmed best based on local resources, will farming “drain” local resources used by others?);
- the quality of hatchery reared fish;
- whether introductions are required, and
- whether it is an exotic or indigenous species?

The potential impacts from introduction of exotics have been well publicized. In fact, freshwater cage farming in Asia relies on exotic species, including the widely farmed tilapia and carps (although carps are indigenous in some parts and have been widely disseminated in the region for many years). Nevertheless, considerable caution is necessary when introducing exotic species and internationally recognized guidelines are available to assist countries (e.g. Turner, 1988). Governments have an important role to play here in helping to establish regulations and encouraging proper import risk analysis to identify and manage risks (e.g. Arthur *et al.,* 2004).

Feeds and feed management

Feed represents a major challenge to the future development of cage farming in Asia. Key issues include:

- use of feeds derived from sustainable resources, reducing reliance on fish resource and reducing as far as possible demand on marine resources;
- making more efficient use of resources in aquaculture feeds.

The choice of feeds and feed management practices by farmers has a major influence, and again considerable opportunities exist to promote efficient feeding practices. There is a strong economic justification for doing so, as feed is a major cost of farming (see above economic section). Therefore, more efficient feeding practices can lead to more

BOX 3

Management and siting recommendations for reducing environmental impacts of cage culture in a highland reservoir used for grass carp cage culture in Viet Nam (modified from Phillips, 1998)

Management practices:

- Use of efficient feeding practices and appropriate diets, which minimize wastage.
- Use of locally available resources, which reduce the reliance on imported materials.
- Possible mixing of intensive and extensive culture/species. For example, filter feeding cage culture could be mixed with more intensive grass carp, to ensure efficient absorption of nutrients and other organic materials produced by intensive cage culture.
- Polyculture to make more efficient use of feed in existing cages, e.g. more widespread use of common carp in grass carp cages and trials to include filter feeding fish in intensive grass carp cages.

Siting and locational factors:

- Siting cages in areas with good water current to ensure good supply of dissolved oxygen and efficient dispersal of waste.
- Spreading out the cages around the reservoir as much as possible to ensure good dilution of waste materials and good oxygen supply.
- Single point mooring of cages to allow cages to move around with the wind, thus helping water circulation and allowing for more efficient dispersal of wastes.
- Controlling water pollution in the catchment area to ensure maintenance of water quality in the reservoirs.
- Siting of cages away from stagnant areas, which are risky because of potential upwelling of poor quality bottom water.
- Ensuring at least 2 m below the bottom of each cage to ensure fish are kept away from potentially anoxic water (low dissolved oxygen, hydrogen sulphide).
- Ensuring the bottom of cages are above any anoxic water caused by a thermocline.

profitable farming. The use of locally available resources can also help to reduce the reliance on imported materials and the risks associated therewith.

Fish disease and health management

Fish disease control is a significant concern in development of cage farming, requiring actions by government and farmer/investor. Key issues are here:

- to reduce risks of fish disease outbreaks by management strategies that reduce stress and maintain suitable environmental conditions for farmed stock.
- to reduce risks of introducing new pathogens into a farm or farming area.

In particular the introduction of new diseases can have severe consequences for investments in cage aquaculture, as they are most difficult to control after having entered an open system. The most recent examples in Asia are the introduction of "koi herpes virus" to Indonesia, which has caused severe damage to common carp cage culture in major reservoirs (as well as pond farms), and which continues to spread, probably through the movement of live fish (NACA, 2004). In Asia, governments have formally agreed on a set of technical guidelines on responsible movement of live aquatic animals in the region; the challenge now is their implementation (FAO/NACA, 2000).

Governments should seek to ensure that farmers have access to professional fish health advice, including extension materials and diagnostic services. A legal basis is also required to control movements of live aquatic animals, thus reducing the risks to farmers from introductions of diseases. Where waterbodies are shared, agreements are necessary between neighbouring countries.

At farm level, there are considerable opportunities to reduce risks from stress or fish disease, including maintaining environmental conditions, on-farm quarantine systems and other measures. Disease control is particularly difficult once outbreaks occur in open cage systems, and cooperation among farmers within a reservoir or lake is important to reduce risks. A major responsibility for investors in countries with limited government capacity for disease control should be to ensure that risks of introducing new diseases are minimized through responsible practices.

Food quality and safety, chemicals and drug use

Aquaculture farms should ensure the food safety of aquaculture products and promote efforts that maintain product quality before and during harvesting. Fish offered for sale should meet the appropriate quality standards for fish intended for human consumption.

Chemicals for treatment of diseases should only be used after diagnosis and treatment recommendation by fish health professionals. Use of chemicals that may impact on human health and/or are banned in importing countries should be restricted. Government has an important role in providing guidance in regulating chemical use in aquaculture (FAO/NACA/WHO, 1999).

Related social issues and other resource users

The development of cage culture can have significant social implications, both positive and negative, and they should be considered in the development of cage farming. Ideally, a community or participatory approach should be adopted for cage farming development, so that developments are suited to the local situation and needs as well as for the identification of appropriate target groups, their role within the community and the expected impact on the community's socio-economic situation.

Training should also be encouraged and tailored to the needs and capacities of the target group(s) identified to ensure responsible aquaculture practices.

Larger company farms should also be encouraged to assess socio-economic impacts and to develop strategies ensuring the benefits' flow to the local communities (e.g. employment, food, avoiding siting in traditional use areas). Finally, cage and pen aquaculture development should – as far as possible (and where relevant) – be integrated within the fishery management systems for waterbodies, rather than being a separate component. In other words, it should be one of the development options for improving fish yields and ensuring equitable distribution of benefits from waterbodies. Whilst sustainable cage aquaculture can increase fish production and income, the challenge is to ensure equitable distribution of long-term benefits to target groups. Therefore, a strong focus on management systems and institutional structures (to support local management systems) is required – alongside the technical issues – to ensure equitable and environmentally sustainable cage and pen culture development.

Management institutions

Management institutions are needed to support the development of cage farming. Lacking local management arrangements and agreements between different stakeholders are a major factor in poorly sited and managed cage culture – and uncontrolled development leads to environmental and social impacts.

Other management factors contributing to cage culture failures include: lack of institutional support/extension service; lack of zoning/permitting plans – haphazard development; a narrow sectoral focus and lack of incorporation into local area planning/reservoir co-management; as well as lack of consideration of social/poverty issues. Technical support (promoting also self-reliance and building capacity of local farmers and farmer/management groups) is needed and development should be based on a balance of local and market needs.

SUMMARY AND CONCLUSIONS

In Asia, cage farming has a long history and continues to expand. Among the various constraints, environmental and market concerns are of particular importance. Management actions by government and by the industry/farming sector are important for the sustainable development of this important part of the aquaculture sector.

REFERENCES

Abery, N.W., Sukadi, F., Budhiman, A.A., Kartamihardja, E.S., Koeshendrajana, S., Buddhiman & De Silva, S.S. 2005. Fisheries and cage culture of three reservoirs in west Java, Indonesia; a case study of ambitious development and resulting interactions. *Fisheries Management and Ecology*. 12: 315-330.

Arthur, J.R., Bondad-Reantaso, M., Baldock, F.C., Rodgers, C.J. & Edgerton, B.F. 2004. Manual on risk analysis for the safe movement of aquatic animals (FWG/01/2002). APEC/DoF/NACA/FAO, 59 p. APEC Publ. No. APEC #203-FS-03.1.

Beveridge, M.C.M. 2004. *Cage aquaculture.* 3rd Edition. Ames,Blackwell Publishing. 376 pp.

De Silva, S.S. 2003. Culture-based fisheries: an underutilized opportunity in aquaculture development. *Aquaculture.* 221: 221–243.

Dey, M.M. & Paraguas, F.J. 2001. Economics of tilapia farming in Asia. In S. Subasinghe & T. Singh, eds. *Tilapia: production, marketing and technological developments*. pp. 33–44. Kuala Lumpur, Malaysia, INFOFISH.

Edwards P., Le Anh Tuan & Allan, G.L. 2004. *A survey of marine trash fish and fish meal as aquaculture feed ingredients in Viet Nam.* ACIAR Working Paper Number 57. Canberra, ACIAR (Australian Centre for International Agricultural Research). 56 pp.

FAO. 1995. Code of Conduct for Responsible Fisheries. p. 41. Rome.

FAO. 2004. *Aquaculture statistics.* 2002. Rome.

FAO/NACA. 2000. Asia regional technical guidelines on health management for the responsible movement of live aquatic animals and the Beijing consensus and implementation strategy. *FAO Fisheries Technical Paper No. 402*. p. 53. Rome.

FAO/NACA/WHO. 1999. Food safety associated with products from aquaculture – report of a joint FAO/NACA/WHO study group, 1999. WHO Technical Report Series No. 883. Geneva, World Health Organization. 55 pp.

Hambrey, J. & Roy, M. 2002. *Final project review of the one-year extension of the CAGES project.* Report for CARE-Bangladesh. Nautilus Consultants, Edinburgh.

Kim, I.-B. 2000. Cage aquaculture in Korea. In I.C. Liao & C.K. Lin, eds. *Cage aquaculture in Asia: Proceedings of the First International Symposium on Cage Aquaculture in Asia*. pp 59–73. Manila, Asian Fisheries Society and Bangkok, World Aquaculture Society, Southeast Asian Chaper.

Liao, I.C. & Lin, C.K. 2000. Cage aquaculture in Asia: Proceedings of the First International Symposium on Cage Aquaculture in Asia. 318 p. Manila, Asian Fisheries Society and Bangkok, World Aquaculture Society, Southeast Asian Chaper.

Medalla, E.M. 1983. On the use of DRC criterion in selecting projects. *PIDS staff paper Series* No. 83–02. Manila, Philippine Institute of Development Studies.

NACA. 2004. Final report of the second meeting of the Asia regional advisory group on aquatic animal health. p. 49. Bangkok.

Nguyen, T.T. & Phillips, M. 2004. *Policy research – implications of liberalisation of fish trade for developing countries. A case study of Viet Nam.* Draft document. Project PR 26109. June 2004. Strategy for International Fisheries Research (SIFAR), Rome.

Phillips, M.J. 1998. Freshwater cage culture development in the reservoirs of the Central Highlands of Vietnam. Phnom Penh, Report to the Mekong River Commission. 124 pp.

Phillips, M.J. 2002. Freshwater aquaculture in the Lower Mekong Basin. *MRC Technical Paper* No. 7. Phnom Penh, Mekong River Commission. 62 pp.

Trong, Trinh Quoc, Nguyen Van Hao & Griffiths, D. 2002. Status of Pangasiid aquaculture in Vietnam. *MRC Technical Paper* No. 2. Phnom Penh, Mekong River Commission. 16 pp.

Turner, G.E. 1988. Codes of practice and manual of procedures for consideration of introductions and transfers of marine and freshwater organisms. *EIFAC Occasional Paper* No. 23. European Inland Fisheries Advisory Commission. Rome, Food and Agriculture Organization of the United Nations. 44 pp.

Van Zalinge, N., Lieng Sopha, Ngor Peng Bun, Heng Kong & Jørgensen, J.V. 2002. Status of the Mekong Pangasianodon hypophthalmus resources, with special reference to the stock shared between Cambodia and Vietnam. *MRC Technical Paper* No. 1. Phnom Penh, Mekong River Commission. 29 pp.

Wu, Z.W., J.W. Guo, J. & Yang, Yi. 2000. Current status and sustainability of cage culture in reservoirs: a case study in China. In I.C. Liao & C.K. Lin, eds. *Cage aquaculture in Asia: Proceedings of the First International Symposium on Cage Aquaculture in Asia*. pp 259–265. Manila, Asian Fisheries Society and Bangkok, World Aquaculture Society, Southeast Asian Chaper.

Cage culture – The challenges

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Cage culture globally is hugely varied, ranging from subsistence level holding of a few kilos of fish in small nets to salmon farms producing more than 5 000 tonnes per year. In Asia more than 50 species are reared in various forms of cage culture. Cage culture can be very profitable, but it is also risky and success is very dependent on local circumstances.

The examined examples of successes in salmon culture, tilapia, spiny lobster and Asian seabass reveal a range of factors which have underpinned the development of the industry in other parts of the world. Strong market demand and well established marketing networks are critical in all cases. In Asia, the availability of both wild seed and low value "trash" fish has been critical to the early stages of development of many forms of cage aquaculture. In the case of tilapia the increasing availability of pelleted feed and the demands of the market for consistent and high quality product have been important drivers. A combination of basic skills (traditional in some parts of Asia, but developed mainly in Universities and research institutions in the case of salmon) and entrepreneurial flare have also been important factors.

Failures have been common however, especially in the case of government or aid driven projects. This is partly owing to the risky nature of cage culture, which requires nurture, commitment and an understanding of local conditions to succeed. Cage culture should be treated as a business, not as a part-time activity. The costs and logistical problems of getting the right quantity and quality of product to market at the right time are commonly underestimated. Local factors, such as predation, theft and vandalism, wind and wave damage can also undermine success. In some cases rapid cumulative high density development has led to environmental degradation and increasing levels of disease.

Cage culture in Africa will only succeed when the five key constraints of seed, feed, finance, skills/information and marketing are addressed comprehensively. While much can be learned from elsewhere, there can be no simplistic technology transfer. Cage design and construction in particular needs to be adapted to local conditions. Feasibility studies must be realistic – costs and lead time are typically underestimated, and returns overestimated. Any new cage culture venture will take significant time to overcome local problems.

The challenge to government and regional organizations is to identify bottlenecks to development and to make short and effective interventions where necessary. A policy and regulatory framework which addresses issues of resource allocation, cumulative environmental impact, and input as well as product quality is also needed.

Cage culture – The Norwegian experience

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ABSTRACT

In a period of only about thirty years, aquaculture has become one of the most important industries in Norway. The natural advantages have been important for the development of the aquaculture industry. However, this development would not have been possible without an endless go-ahead spirit among the pioneers as well as planned research and development of a well-adapted public administration. What has been achieved is an increased knowledge about the importance of choice of site, better adapted technology and feed, and an increased knowledge about management. These have had several positive effects, among others reduced production cost, lower environmental impact and improved fish welfare. The improved fish welfare together with a research program for development of vaccines has reduced the use of antibiotics to a minimum. Also, breeding throughout the year has played a major role in the development of the industry into a highly effective producer of high quality food. With an increased production it has been necessary to have a regulation and legislation adopted with the development of the industry. Of vital importance has also been the development of new and existing markets, and the ability to find consumers for the increased quantity of fish produced.

To keep up and further develop markets, the production costs must be further reduced. This should be achieved without any negative effects on the fish welfare and the environment. Public opinion follows the industry closely and a production that is not sustainable will have a negative effect on the local and international market. Production, market and public standing are closely linked to each other.

INTRODUCTION

In a period of only about 30 years, aquaculture has become one of the most important industries in Norway. What is the reason for this? Is this "fairy-tale" a result of planning and foresight, both from the industry itself and from the politicians and the governmental system, or did it just happen?

THE HISTORY

In the 1950s and 1960s people tried to grow rainbow trout "the European way", i.e. portion size (200–500 g) in freshwater ponds. This never became a success in Norway, and many people had to leave the business. Fish diseases, technology and water quality were problems facing the fish farmers. In the late 1960s/early 1970s some pioneers tried to farm salmon in seawater, first by pumping seawater into onshore dams and tanks, later the idea of sea cages was born.

The Norwegian fish farming history is a history about trial and failure during the last approximately 30 years. It has developed from almost nothing in the 1960s to a production of about 600 000 tonnes of salmon in 2003. It is more or less entirely based on the production of Atlantic salmon (*Salmo salar*). There is also a smaller production of rainbow trout (*Oncorhynchus mykiss*), some cod (*Gadus morhua*) and mussels (*Mytilus edulis*). Throughout the last 30 years salmon farming has developed from a small-scale local industry to the current worldwide industry.

NATURAL ADVANTAGES

Norway is one of the countries in the Northern hemisphere blessed with a number of wild populations of Atlantic salmon in the rivers. The salmon has always had an economical impact and has been exploited in many ways, both in freshwater and in the sea (as a food source and for sport fishing). As a consequence, an early interest was taken in the biology of the salmon and also in enhancing its growth potential. This knowledge was one of the key factors when salmon farming started. Norway has always been a fishing nation, and hence the coastal inhabitants had gained knowledge about how to keep fish in nets, about handling, adding value and exporting fish. This traditional competence came to use in salmon farming. In addition, the fishing industry made it possible to receive local foodstuff for the growing of salmon and trout. Last but not least, Norway had an infrastructure along the entire coast. There were small communities and people in place that knew the fish and the sea. And there were very good conditions for salmon and trout in sea, given by nature.

All knowledge and the resources mentioned above were crucial for the success of the industry.

CAN ANYTHING BE LEARNED FROM THE NORWEGIAN EXPERIENCE?

The natural advantages have been important for the development of the Norwegian aquaculture industry. However, this development would not have been possible without an endless go-ahead spirit among the pioneers, planned research and a development of a well-adapted public administration.

Technological and biological development

The development of an aquaculture industry depends on research and the availability of new knowledge. Research and development (R&D) has not always been in pace with the growth of the industry. Because the industry expanded so fast, the need for knowledge was crucial. The authorities' grants were too small according to the industry's opinion. The fish farmers were convinced that more R&D was needed, and during the 1980s different research programmes were launched through funds payed by the industry itself:

- "Healthy fish" in 1983 with the aim of looking into different aspect of fish diseases.
- "New species in marine aquaculture" in 1985 to do research on possible species that could have a potential in culture.
- "Quality fish" in 1988 which was a cooperation between the industry and the authorities, aiming to increase professional knowledge about quality, quality measures and information to the industry.

They all evolved into national research programmes, and were partly financed by the industry. The results from those programmes (and other relevant R&D) have been a good scientific base for the development of the industry until today. Along with this, a mutual understanding and trust between the industry and research institutions evolved. This in turn led to a short distance between the producer and the scientist, which has had a strong impact on the development of the industry.

Breeding

Breeding programmes are important in domestication, also when it comes to aquaculture. Historically, competence in this matter was transferred from the agriculture sector (see below), but from the beginning of the 1970s a central research station (i.e. Akvaforsk owned by the Ministry of Agriculture) started a breeding programme on salmon and later on rainbow trout. In 1984, the fish farmers decided to establish their own breeding station, and the Norwegian Fish Farmers' Breeding Station started its operations in 1987. The building costs were about US$5.5 million. The breeding aims for salmon were concentrated around fast growth, late maturation, colour and fat content. Later on also resistance against diseases, shape and skin colour were included. There are no doubts that what has been gained through breeding throughout the years has played a major role in the development of the industry into the highly effective producer of high quality food that it is today.

Fish health

The Ministry of Agriculture was responsible for providing veterinary services, and as early as 1967 they employed a veterinary especially in charge of fish diseases. In 1968, the "Fish Disease Act" was adopted to prevent, control or eradicate diseases in freshwater fish. This was very important for the future development of aquaculture, because the central authorities through the Ministry of Agriculture then took on the overall responsibility for prevention and control of fish diseases.

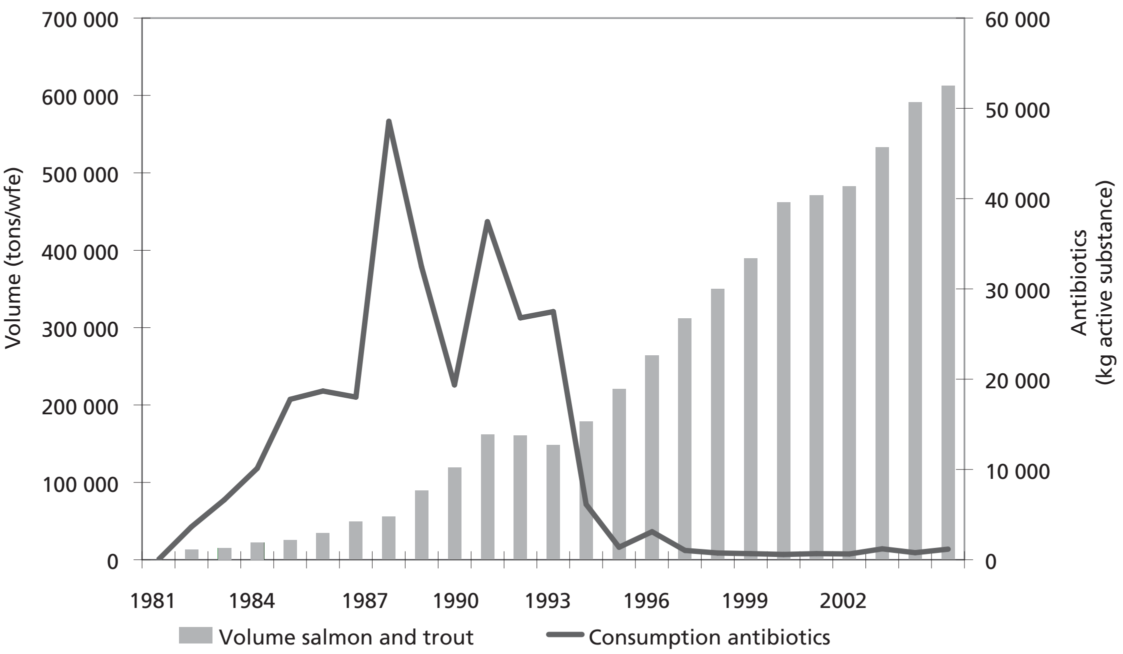
Because of the high demand for smolt, these were imported from Scotland in 1985, approved by the authorities. This turned out to be fatal, because along with the smolt, the bacterial disease Furunculocis (*Aeromonas salmonicida*) was introduced into Norwegian aquaculture. This was a new disease for Norwegian fish farmers, and a heavy eradication and control system was launched in cooperation between the fish farmers and the authorities. The treatment against the disease included the use of antibiotics in substantial amounts. An effective control of the disease was obtained by the development of vaccines. In the middle of the 1980s, another disease occurred that had not been described earlier. It was concluded to be caused by a virus; the disease was named Infectious Salmon Anaemia (ISA). It causes heavy mortality, and the strategy to control it is to keep the outbreaks at an absolute minimum.

The general plan for control, eradication and prevention included the demand for health control and health certificates in smolt production and transport, regulations of transportation, regulations of treatment of waste and blood water from slaughter houses as well as the establishment of disease fighting zones. This close cooperation has been crucial for the result, and annual outbreaks have been low since. The bacterium Cold Water Vibriosis (*Vibrio salmonicida*) caused heavy mortalities in the second half of the 1980s, but through better understanding of fish farming husbandry, better feed and effective vaccines, this disease has been under control include fallowing after a production period.

Market

The producers were aware early of the damage bad or fluctuating product quality could do to the market. Criteria for quality of slaughtered salmon and trout were therefore launched by the Fish Farmers' Sales Organisation and The Norwegian Fish Farmers Association and soon adapted as a part the quality regulation and legislation. The customers then knew the quality of what they bought and were certain that they also would get that same quality the next time.

FIGURE 1
The reduction in use of antibiotics in aquaculture production of salmon and trout



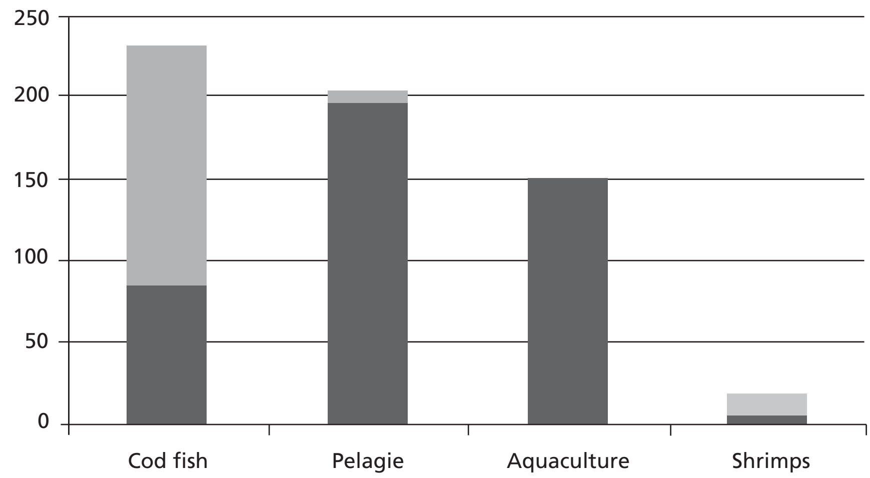
Regulation and legislation

The interest for fish farming was growing, and there was a discussion about which ministry should have the responsibility for the new industry. Should the Ministry of Agriculture, the Ministry of Environment or the Ministry of Fisheries be responsible for the farming of salmon and trout? The Norwegian Fish Farmers' Association (NFF) suggested that an official committee should look into the matter and give its advice to the Norwegian Government. This was accepted and the committee started its work in 1973. One of the first things it did was to propose the need for a law regulating fish farming. The committee gave its conclusions and recommendations in 1977. Different interest groups had different views about the placement of the administrative responsibility for fish farming within the Norwegian Government. As a consequence of the conclusions and recommendations given by the committee, the Parliament in 1980 decided that the Ministry of Fisheries should be responsible for fish farming, and that fish farming should be developed into an independent industry free of subsidies. The competing view was that fish farming should be part of the Ministry of Agriculture's responsibility, and should evolve as part of existing farms along the coast. The Fish Farmers' License Act of 1973 was a tool for controlling and guiding the development of fish farming, and was meant to be provisional. The fish farmers themselves (through NFF) enforced the coming of the act. The following points were the most important parts of the act:

- all fish farming units in operation should be registered;
- permission is needed for fish farming, and permission should not be given if the plant
- could cause risks for outbreak of fish diseases;
  – could cause risks for pollution and
  – had too low technically standard, or if the site was not suitable;
- restrictions on the size of the fish farm (licence), i.e. max. number cubic metres of production volume.

From then onwards, everybody that wanted permission (license) for farming salmon and trout had to apply for a license from the authorities, and a certain volume

FIGURE 2
By-products utilised /dumped in 2004 (1 000 tonnes/year)



in cubic metres limited the license. Permissions were given liberally until 1977. Then, the production capacity was seen as sufficient and no new licenses were issued before 1981. At that time there were 438 licenses issued and the slaughter volume was about 4 300 tonnes.

In 1981, the temporary Fish Farmers' License Act of 1973 was replaced by a new provisional Fish Farmers' License Act. Licenses should not be given if the facility:

- could cause risk for spreading disease among fish (according to the Fish Disease Act of the Ministry of Agriculture);
- could cause risk of pollution (according to the Act on Pollution of the Ministry of Environment) and/or
- interfered with other legal interests or was technically not sound.

During the 1980s, the aims of the regulations of the industry as given by the government were:

- to regulate the production of farmed salmon/trout in Norway in accordance with market demands;
- to have a regional distribution of fish farms;
- to have an owner–operator structure of the industry;
- to give a legal person the opportunity to have majority owner-interests in one farm only.

The law of 1981 was replaced by a new, permanent Fish Farmers' License Act in 1985. The Ministry of Fisheries had the responsibility to decide the total number of new licenses and the regional distribution of these. From 1981, the authorities have given out a specific number of licenses, geographically distributed, and this practice is still followed today. The regulation in cubic metre was chosen by the authorities, because this way they could protect the environment (production limit). Indeed, the maximum volume allowed would facilitate the development of an industry with small-scale facilities, hereby including regional politics. It also contributes, together with the issuing of licenses, to limit the production in accordance with market demands.

Feed quota

In June 1996, the Scottish Salmon Growers Association launched a complaint to the Commission of the EU, accusing Norway of dumping salmon in the European market, in addition to receiving subsidies. After conducting investigations in Norway the EU Commission recommended imposing provisional duties on Norwegian farmed salmon to the EU. However, the Antidumping Committee rejected this recommendation, and the EU Commission was advised to come up with an alternative solution regarding Norway. "The salmon agreement" came into effect 1 July 1997 and expired 2003.

As a result of the salmon agreement the fish farmers asked for regulations through feeding quotas. Through regulation, each license (12 000 cubic metres) was appointed a certain amount of feed, which could be used throughout one year. The size of the quotas was regulated each year by the Minister of Fisheries, based on statistical figures of available smolt, biomass in sea, markets, etc. Because of this regulation the production was much more predictable than before.

Environment

On the environmental side, the industry is facing two main challenges, i.e. to reduce the number of salmon escaping from farms and to achieve a better control of sea lice. Apart from the damage escapees do to the industry, they may cause negative interactions with populations of wild salmon. The fish farmers have steadily worked for better equipment, especially when sites are located in rougher localities. A certificate for new equipment has been introduced, implying that equipment shall meet certain technical standards in relation to the degree of exposure. A monitoring system for evaluating the environmental standard of the localities and their carrying capacity will be introduced. The use of antibiotics in salmon and trout culture has reduced drastically in the early 1990s (Fig. 1). Aquaculture will also be a part of coastal zone management in Norway.

In fish farming, the fishing and processing procedures create a large amount of waste. However, this should be regarded as a resource rather than waste. The different branches of the fishing industry (aquaculture, processing, fishing) and the three ministries responsible for fishing, environment and fish health together with the Norwegian Research Council started a foundation in 1992. The aim of this foundation was to support R&D in such a way that wastes/by-products from the industry could be converted into a resource. Today, the aquaculture industry is recycling more than 95 percent of what was called waste earlier. While fish farmers had to pay for getting rid of the waste in the past, they can now do it for free or are even paid for it.

By-products from Norwegian fisheries, included fish farming consist of viscera (liver, roe, stomachs, etc.), heads, backbones, cuts and rejected fish from processing. The by-products are generated when the fish is gutted, headed and further processed either on-board in fishing vessels or in processing plants on shore. Today most of the by-products are used as raw materials for feed production; such as fish meal, silage and feed for fur animals (Fig. 2). The total value adding represents 125 mill. € (2003).

Organization

In March 1970, the fish farmers founded "The Norwegian Fish Farmers' Association" (NFF). The aim of the association was to "gather all the fish farmers in one association working for the fish farmers economic, professional, social and cultural interests". That meant the fish farmers spoke with one voice, and therefore had the opportunity to become an important part in making the future framework for the industry. Knowledge was scarce, and one of the tasks for NFF was to play a major role in the network building between members as well as in the gathering and distributing of information to members. The need for information led to the foundation of the Norwegian Fish Farmers' Magazine in 1976, which has made a significant contribution to the spreading of information, research results, etc. The organization has always cooperated closely with the authorities, in particular with the Ministry of Fisheries, the Ministry of Agriculture and the Ministry of Environment, which are in charge of the industry. Furthermore, the organization had been heavily involved in research and development, education and all relevant issues related to the aquaculture industry. There is a fairly good understanding that the organization wants a regulated industry, while it also wishes to play a major role in framing the regulations (which has been achieved). From the very beginning, the organization wanted to build an independent industry free of any subsidies, which today is the case.

In 2000, NFF merged together with organizations representing the fishmeal and fish feed producers as well as the industry into FHL (Norwegian Seafood Federation). The organization continues to play an essential role in the future development of the aquaculture industry.

SUMMARY

Through determined efforts in R&D and through cooperation the industry has had a tremendous development in feed, feed technology, equipment and technology as well as vaccines. This in turn has made it more cost effective and has been crucial for its successes as a producer and exporter of farmed salmon and trout.

However, there is an increased competition from other salmon producing countries. To keep up and further develop both exciting and new markets, the production costs must be further reduced. This should be achieved without any negative effects on the fish welfare and the environment. A production that is not sustainable will have a negative effect on the local and international market. Production, market and public standing are closely linked to each other.

To be able to do so, the future challenges will be related to:

- expansion of markets;
- environmental matters;
- coastal zone management;
- value added products;
- international trade and customs;
- food safety;
- documentation;
- alternative/new feeds;
- new species in aquaculture.

Cage aquaculture in Italy – General overview and technical considerations

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ABSTRACT

This paper provides an overview of the Italian cage culture industry developed during the last 15 years exclusively in marine environments along the Italian coastline. Some relevant issues that could deal also with a freshwater cage farming framework are given in addition. The total 2003 cage production of the two most widely farmed species in Italy, the European seabass (*Dicentrarchus labrax*) and the Gilthead seabream (*Sparus aurata*), can be estimated at 2 000 tonnes and 2 800 tonnes, respectively. This quantity represents about 30 percent of the national production of these species. Recent cage farming of bluefin tuna (*Thunnus thynnus*) fattening practice is also reported.

The cage farming activity is not yet completely regulated and most of the procedures regulating the licensing system are demanded by the regional or municipal authorities. Licence release is subjected to the submission of an Environmental Impact Assessment, and often (it is discretion of the releasing authority) the results of an "Environmental Monitoring Programme" (EMP) which could entail periodical analysis on sediments and water column. Different cage types are used, depending on the selected site, the economical resource and the production strategies. The most widely used are made of High Density Polyethylene pipes, but also "Farmocean", "REFA" tension legs and a floating platform are present. The boats used for cage culture can be divided in three categories: working boats equipped with crane, feeding boats carrying a feeding system and auxiliary service boats. Usually the cage farms are provided with inland facilities that can be summarized as: a packaging area, a feed warehouse, an area dedicated to the net maintenance and stocking as well as offices and laboratory.

Biomass-related errors can cause an economical and environmental risk. Main attention should be given to the number of the fish in each reared batch paying attention to the exactness of the initial input, reducing the uncontrolled output (escapees, predators, cannibalism and thefts) and reporting any controlled output (mortality, samples, harvest). Several environmental impacts could be ascribed to the cage farming, i.e. visual alteration of scenic places, modification of natural current pathways, chemical and organic pollution, escapees. All efforts must be made to minimize the negative effects, mainly by doing an environmental impact assessment in the preinstalling phase, adopting an environmental monitoring programme during the farming activity and applying a correct management of the fish. The cages are an open system that allows exchange of pathogens between cultured and native fish. Therefore, any stocking of fish must ensure the healthy status of fingerlings

and, once caged, the farming practice must be optimized to avoid the outbreak of diseases already present in the local fish populations. Medical treatments must be applied only if necessary and under veterinary surveillance, using authorized chemicals.

INTRODUCTION

Cage farming in Italy is a recent activity that has been completely developed in the sea and that can be considered being in progressive development from a technological and biological point of view. The first commercial experiences of intensive cage farming in Italy started in the late 1980s. In 1989, the company "Sicily Fish Farm" began its offshore cage fish farm in Sciacca, in southern Sicily. Then in 1990, there was "Spezzina Acquacoltura" near Genoa; in 1991 "Aqua Azzurra", a fish farm that already operated a hatchery and inland rearing facilities, started its cage production in Pachino, south of Sicily. In 1993, "Compagnie Ittiche Riunite" (C.I.R.) in Golfo Aranci, Olbia, and in the following year, "Med Fish" in Gaeta, near Rome, began their cage production.

ITALIAN CAGE PRODUCTION

Currently, 34 cage farms producing the European seabass (*Dicentrarchus labrax*) and the Gilthead seabream (*Sparus aurata*) are operating in Italy, most of them located in the south also thanks to public (both national and from the European Commission) subsidies allocated to investments in depressed areas (Figure 1).

Small quantities of Sharpsnout seabream (*Diplodus puntazzo*) are occasionally produced. Other species, such as Common dentex (*Dentex dentex*), Common seabream (*Pagrus pagrus*) and meagre (*Argyrosomus regius*) are reared but only as pilot experiences to test the productivity under farming conditions and the market response (marketability) of the new species. Out of the 34, 11 farms have closed mostly between 2000 and 2002.

In 2003, cage production in Italy of seabass and seabream was estimated at 2 000 and 2 800 tonnes, respectively (Associazione Piscicoltori Italiani, pers. comm.) (Figure 2), with an increasing production forecast. This quantity represented about 30 percent of the national production of these species (Figure 3, page 84).

In the period from 1999 to 2003, an increasing import of low cost product from Greece has been reported (Figure 4, page 85), which has caused a drop of the market price (Figure 5, page 85) causing a sector crisis responsible for most of the above mentioned failures; only in the last two years a recovery of the price has been registered.

Recently, also the "Bluefin Tuna Industry" has started its activity with the installation of three fish farms in Sicily two in Calabria and one in Campania, The total production (output from cages) in 2003 was 1 700 tonnes (Table 1, page 86), sold fresh and chilled mainly on the Japanese and US markets.

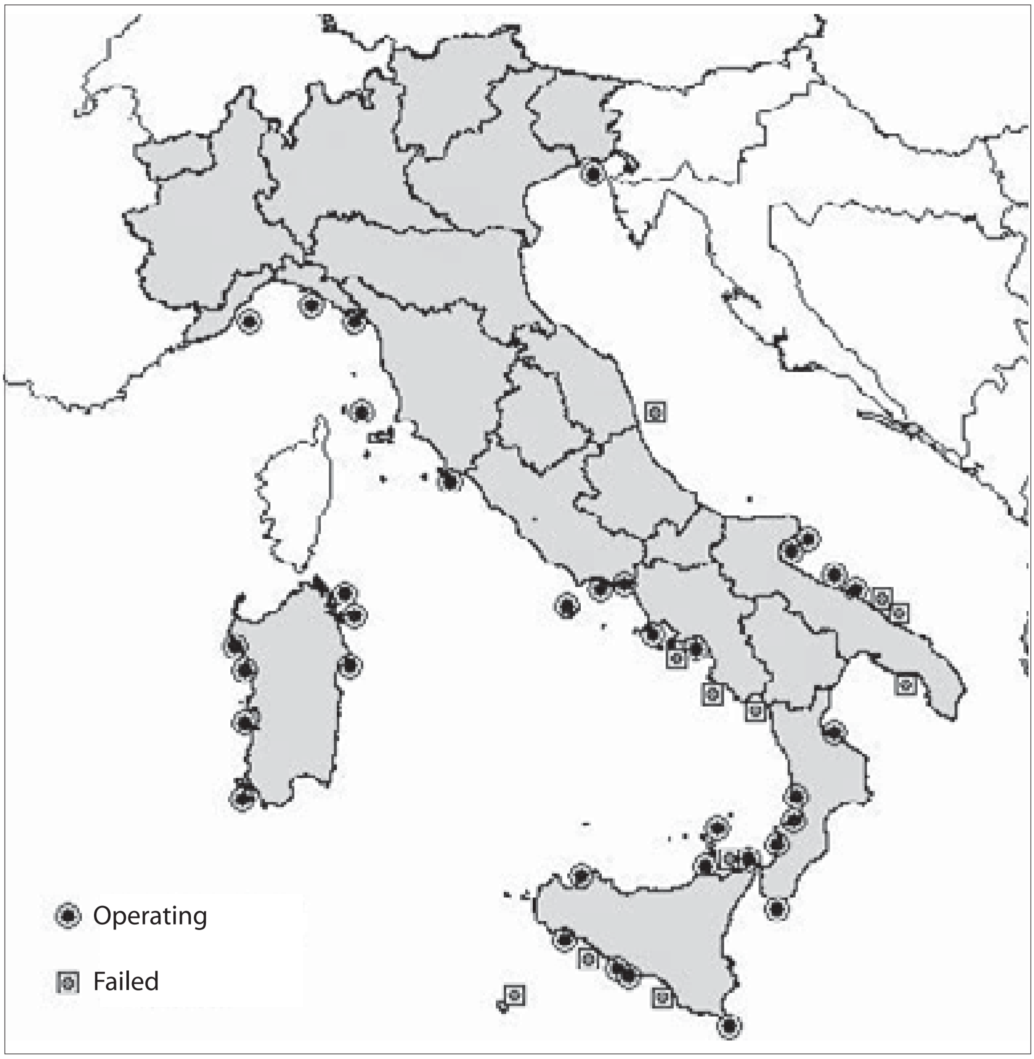
Schools of tuna are mainly caught in the Sicily channel or in the Tyrrhenian Sea and the batches are stocked in floating HDPE circular cages, from 30 up to 50 meters diameter.

INSTITUTIONAL FRAMEWORK

The Italian laws and regulations are very fragmented and none is specifically made for cage culture. There are provincial, national, and European regulations to be considered in the aquaculture sector. The licensing system is managed by the provincial authorities and often is delegated by the Province ("Regione") to the municipal administrations[1].

[1] "The National Fisheries and Aquaculture Plan for 2004 (Ministerial Decree of May 7th, 2004) reports that the administrative powers concerning aquaculture management have been transferred to the Regional Authorities, while general guidance and coordination tasks are still performed by the Central Government, especially as regards the interaction with capture fisheries" (FAO/NALO for Italy, 2006).

FIGURE 1
Locations of Italian cage farms producing Gilthead seabream and European seabass.



Aquaculture has had a specific law since 1992 (Law 102 of 5 February 1992 "Rules regarding aquaculture activity") but cage aquaculture is not entirely regulated, because of its recent development and "experimental" nature in those years.

The establishment of a cage fish farm is subjected to an administrative licence released by the local authority (regional council or municipal authority). To obtain a licence for the occupation of sea surface, entrepreneurs must submit a request to the responsible local authorities together with an environmental impact assessment and a technical project paper, describing all the details (social, economical and biological) of the planned activity. The local authorities will forward the request to all the institutional subjects that could be involved with the farm activity (i.e. Harbour Office, Municipal Building Commission, Local Board of Health, Environmental Authorities, Custom Office, etc.) to obtain their clearance. Once all the involved authorities release their approval, the licence is issued. The whole process could take up to four to five years, which is one of the limiting factors for a competitive development of the sector. In fact, an initial economic assessment of the activity could be no longer valid after this period of time, for instance because of a high variation of the market price of

FIGURE 2
Trends in Italian cage production of Gilthead seabream and European seabass (Associazione Piscicoltori Italiani, pers. comm.)

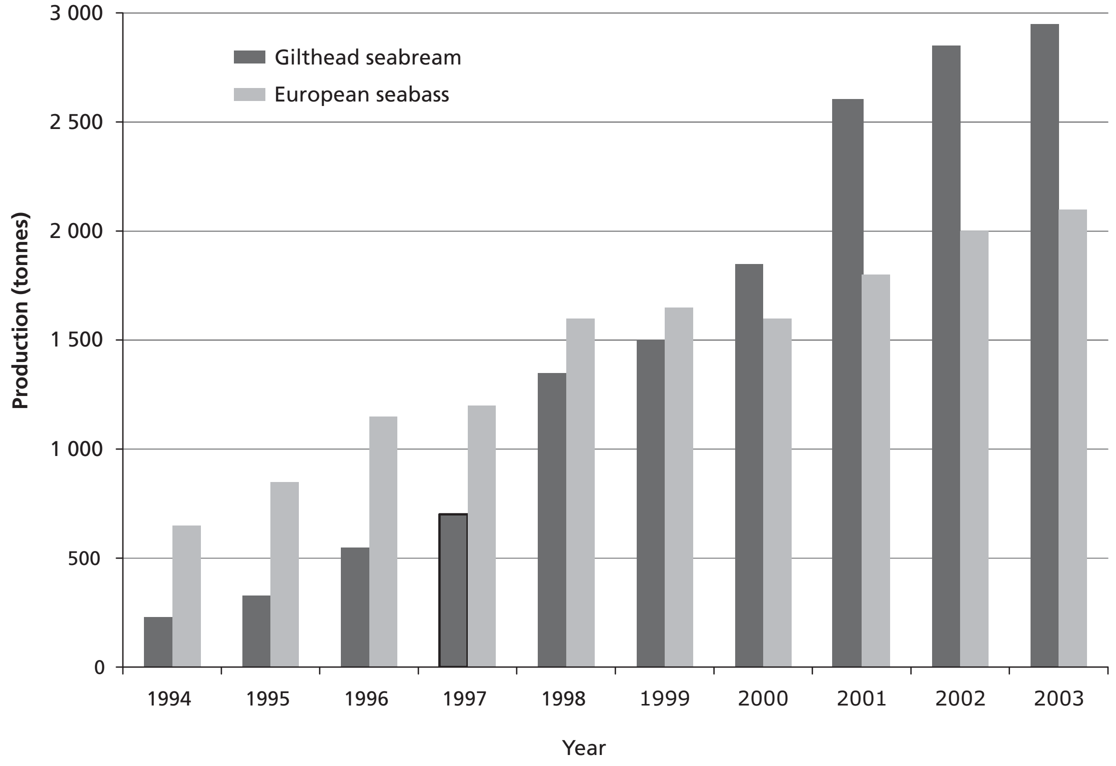


FIGURE 3
Gilthead seabream and European seabass: Total production and cage production (FAO, 2004 and A.P.I., pers. comm. 2004)

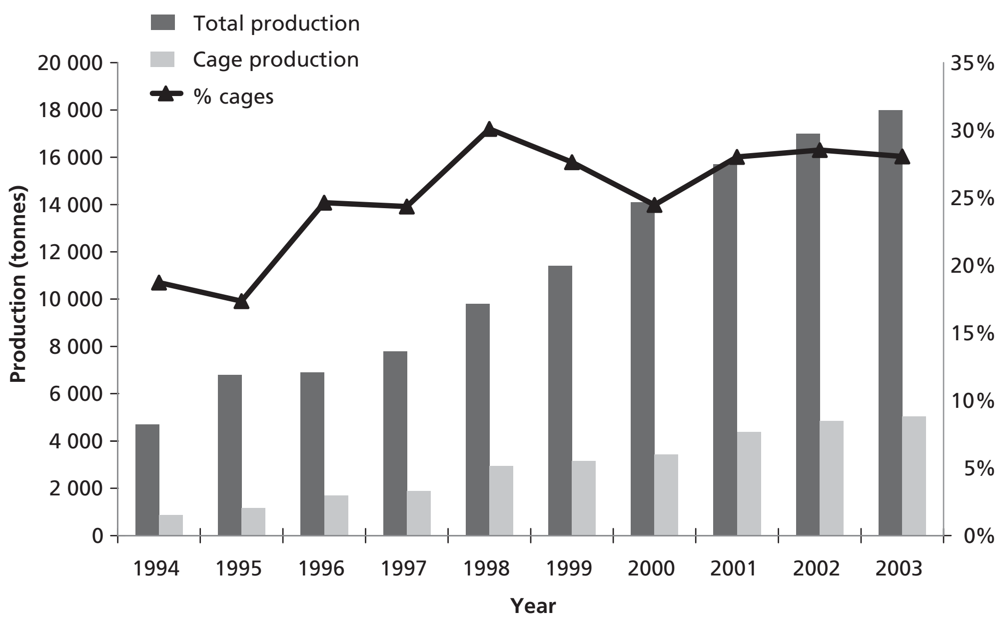


FIGURE 4

Mean annual Italian consumption and imported quantities of Gilthead seabream and European seabass (ISMEA 2004, A.P.I. pers. comm. 2004)

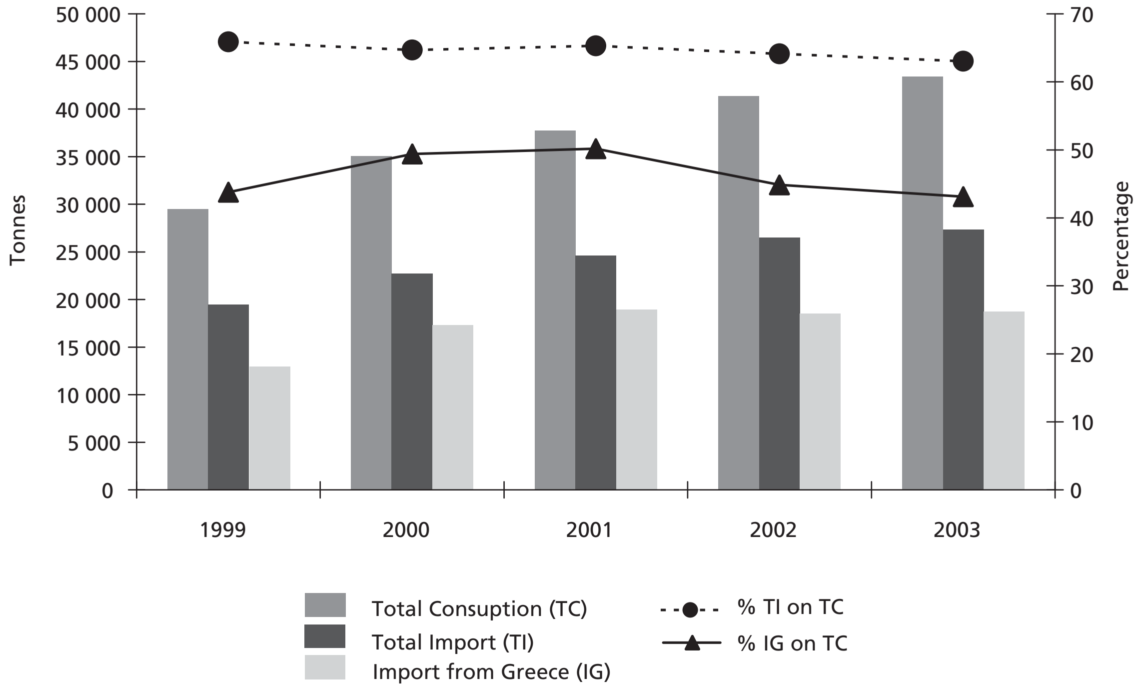


FIGURE 5

Trends in mean price of Gilthead seabream and European seabass in Italy (FAO, FISHSTAT+, 2005)

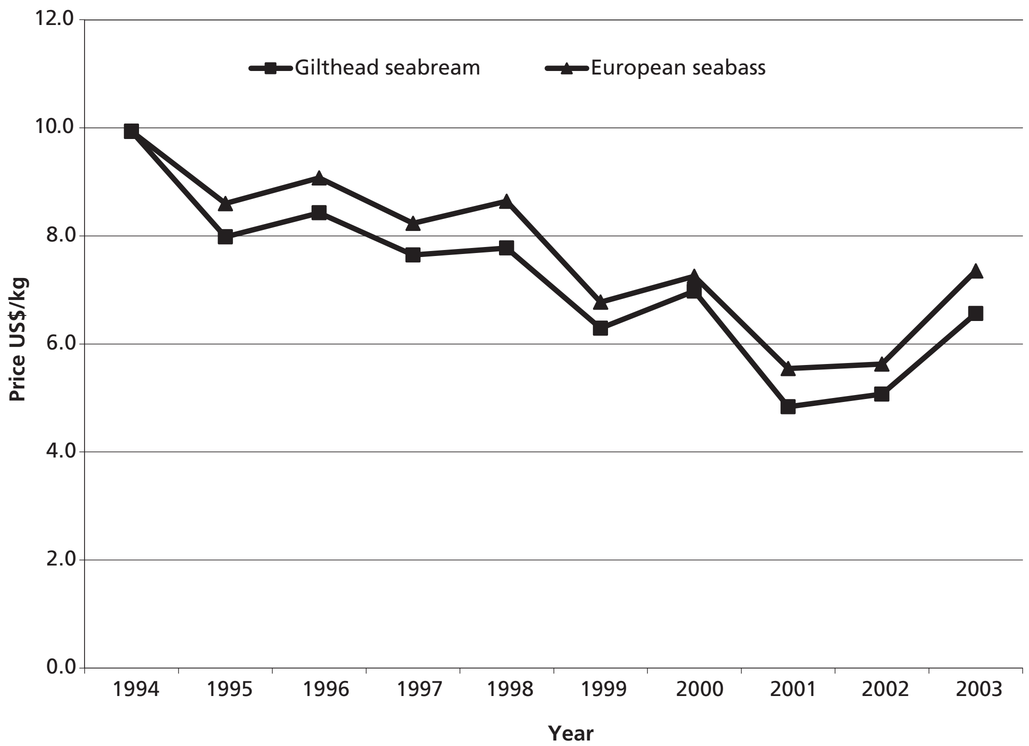


TABLE 1
Bluefin tuna (BFT) production in Italy. Production, size range and mean size (FAO/ICCAT, 2005)

Year	BFT produced (tonnes)	BFT size range (kg)	BFT mean size (kg)
2001	800	35-250	150
2002	1800	35-200	120
2003	1700	30-300	130

the product. Usually, licences are subjected to an EMP that must continue for all the operating period of the farm. The licences expire after ten years and renewal is almost automatically granted.

CAGE DESIGN

Numerous types of cages are used in Italian fish farms and the choice is related to several factors:

Siting

The most important aspect to be considered is the site where the cages will be set up and their suitability for:

- exposure to potential sea storms;
- average sea conditions and
- visual impact.

An exposed site connected with an increased risk of heavy storms, will require cages, nets and mooring systems projected to resist to the maximum registered strength of storm. If the site is quite sheltered, a simplified mooring system and lighter rearing structures will reduce the cost of the initial investment. If there could be negative interactions with the tourist activity on the coast, a submerged model of cage shall be taken into consideration or could be prescribed by the administrators releasing the license.

Cost of cages

The initial cost of the investment represents a limiting factor, especially for those investors managing a fixed budget. The cheapest solution could result in neglecting the suitability of the structures for the site.

Production plans

The size of the farm and the model of cages may vary depending on the target of the investors. For instance, farmers wanting to produce a niche product and attempting to diversify the offer through various sizes of fish or rearing new species, prefer a large number of small cages instead of a few large cages.

Farmocean

These cages (Plate 1) are semi-submersible rigid cages, designed with a rigid steel framework developed in the 1980s, as a result of offshore farming system research in Sweden. The net is fixed inside the main floating hexagonal frame and its shape is maintained by a sinker tube attached to the bottom. The size range of these cages goes from 2 500 up to 5 000 cubic metres, and each cage is moored through three main radial lines. An automatic feeding system is placed on top of the floating frame and could store up to 3 000 kg of feed; energy is supplied by solar panels.

Plate 1
Farmocean offshore cage system (Farmocean International)

Advantages:
- meanwhile tried and tested over 16 years in a large variety of conditions;
- suitable also for exposed sites;
- integrated feeding system;
- stable holding volume.

Disadvantages:
- high capital costs;
- complicated access when harvesting;
- difficult to change the nets;
- requires high maintenance.

REFA tension leg

Plates 2 and 3 show cages composed of a net kept in shape by submerged buoy and an inferior rigid frame. The mooring system is composed of six concrete blocks, located on the bottom vertically under each cage. On top of the net there is a circular HDPE collar that keeps the part of the net where feeding is carried out on the sea surface. During the storms the cage takes a submerged position because of the current on the net thus leading to a reduction of the rearing volume.

Advantages:
- simple design and automatic response to bad sea conditions;
- cost effective;
- small bottom area occupied by the mooring system;
- easy to repair;
- few components require maintenance.

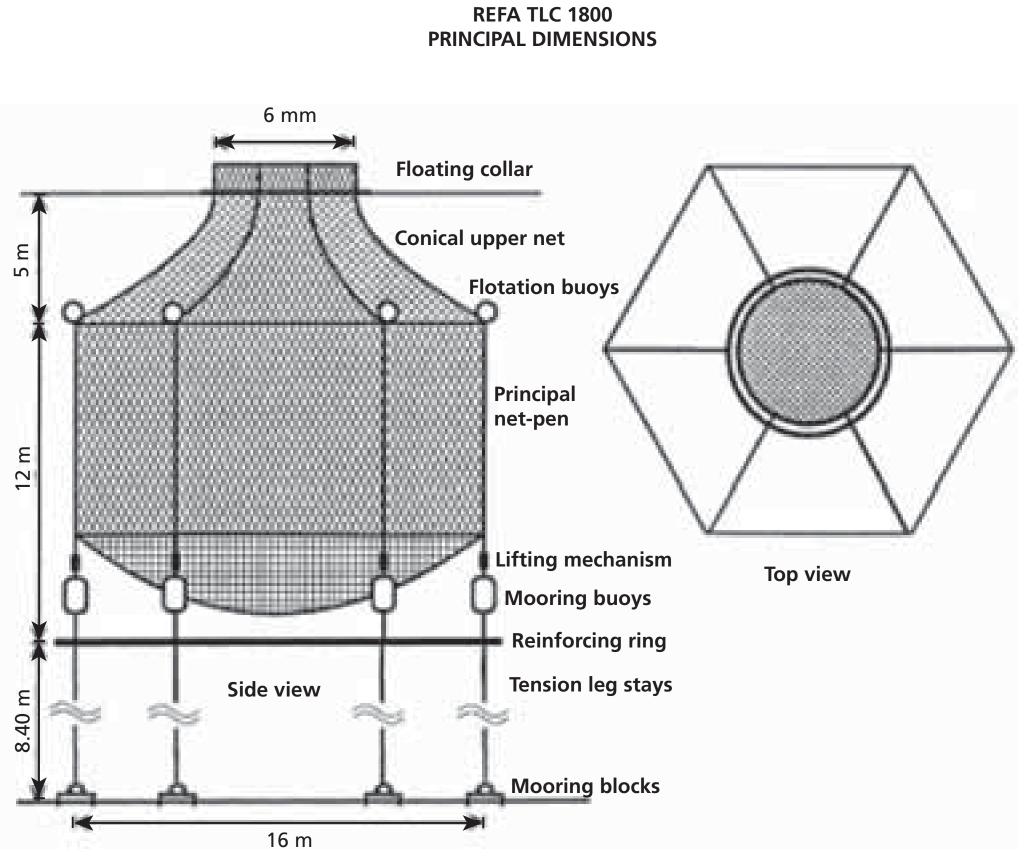


Plate 2
REFA Tension Legs cage design (side view and top view), Refa Med Srl

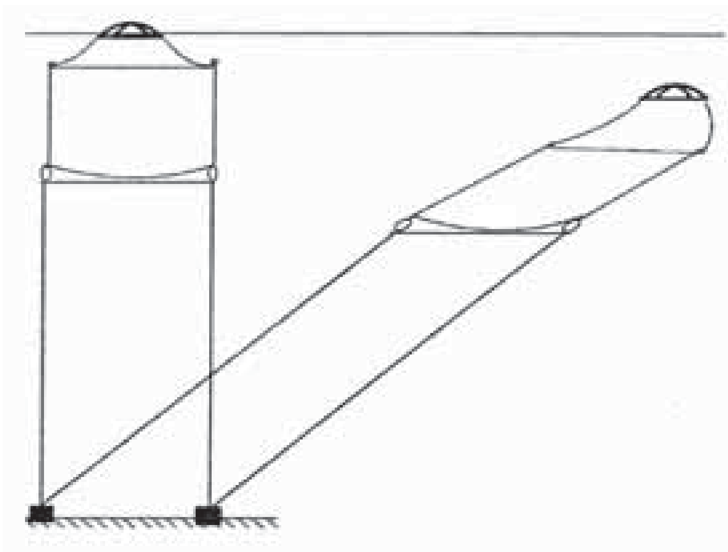


Plate 3
REFA Tension Legs cage in storm conditions (side view), Refa Med Srl

Disadvantages:
- poor visual check of the fish, because of closed cage design;
- small surface for feeding;
- difficult to change the nets.

Floating platform

Following the Spanish experiences where several platforms (mainly produced by the Marina System Hiberica Ltd) were built to keep the nets, in Italy a pilot project was developed in the 1990s for the implementation of a platform where also other facilities, such as packaging hall and lodging for the staff, were available. This structure (Plates 4 and 5) became operational in 2000; it is composed by a 60 meters wide circular iron structure where six nets of 5 500 m^3 each are fixed. In the centre there is a 10 × 20 m building divided in two floors: downstairs the packaging area with cold store and ice producer, upstairs the staff lodging with kitchen, meeting room and canteen. It is currently moored on 80 m at sea bottom and the system is composed by only one single line of 300 m which allows the structure to rotate on a large surface to better disperse fish waste. Power is supplied by two generators and a sinking system allows to rise the floating level of the structure during storms.

Advantages:
- excellent logistics;
- possibility of feeding under any sea condition;
- constant visual check of the fish;
- supposed to be a long lasting structure.

Disadvantages:
- high initial cost of investment;
- additional operational costs for divers;

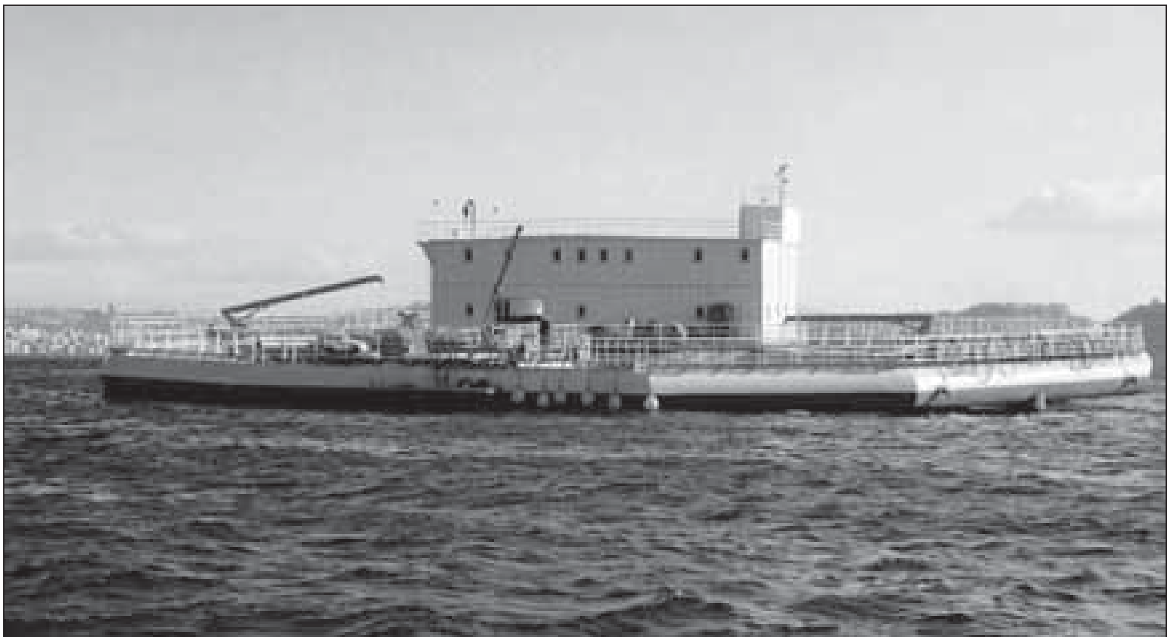


Plate 4
Floating platform cage design in the Pozzuoli Gulf, Naples.

Plate 5
The floating platform in the Pozzuoli Gulf (Naples), one of the six nets, 5 500 cubic metres each

Plate 6
HDPE circular cage design, Lavagna.

- high maintenance costs;
- difficult to change nets.

High Density Polyethylene (HDPE) cages

This kind of cage (Plate 6) is one of the types used mostly in Italian fish farms. The HDPE pipes can be assembled in various ways to produce cages of different sizes and shapes. The main supplier companies are, among others, Floatex, Corelsa, Polarcirkel and Fusion Marine, however self-built cages are used as well (Plate 7). They are often composed of two rings of HDPE pipe kept together by the base of several plastic

Plate 7
HDPE rectangular cage. Self-built by farmer, Licata.

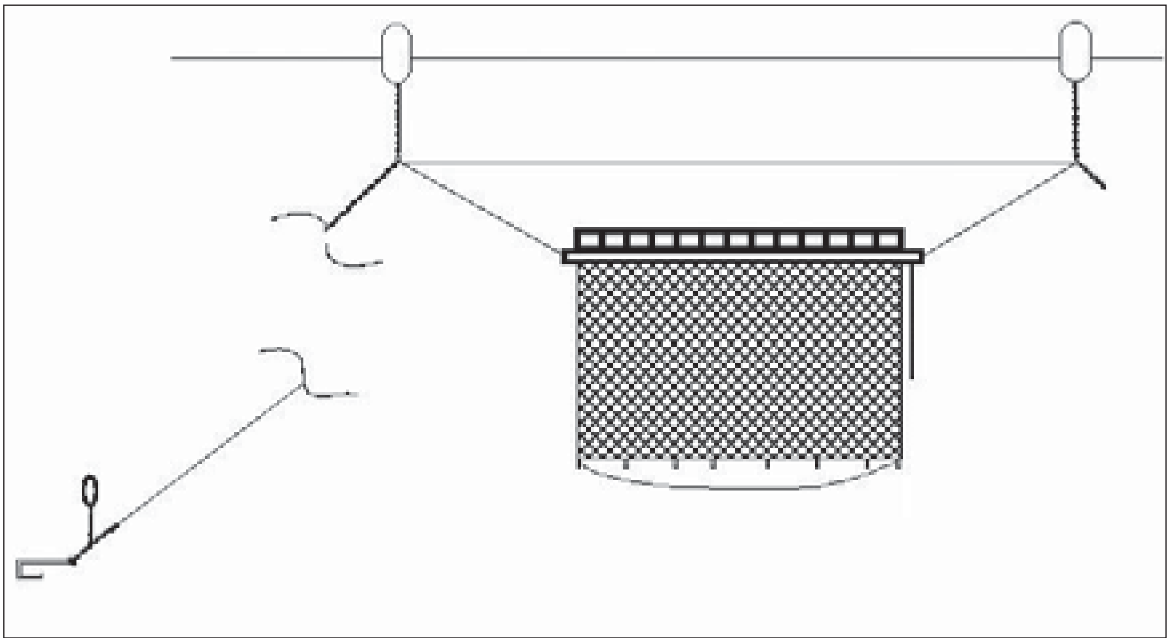


Plate 8
HDPE circular cage. Sinking position in storm condition, Polarcirkel.

or HDPE stanchions disposed through the entire circumference. The rings can be floating (filled with polystyrene) or sinkable (provided with flooding water/air hoses) (Plate 8). The net is fixed at the base of each stanchion and is completely closed with a net cap if the cage is submersible. On the bottom several weights or a sinker tube are fixed. Cages of various diameters are available onto which nets as deep as the site allows are fixed. The mooring system is often quite complicated: a square shaped grid composed by ropes, iron plates and buoys; the cages are moored onto the plates. All the grid is moored with anchors or concrete blocks through several orthogonal lines.

Advantages:
- versatility of the materials;
- simple to change the net;
- frequent visual check of the fish;
- relatively cost effective (specially for bigger cages).

Disadvantages:
- complicated mooring system with linked frequent maintenance;
- the submersible system is not automatic;
- to submerge the cages is time consuming and a constant weather forecast check is needed.

PRODUCTION SUPPORT FACILITIES

Boats

The working boats are often underestimated in the project phase of the fish farm and several companies have been forced to upgrade, or even change, the first main boat of the farm.

For efficient cage farm operations a minimum of three kinds of vessels is suggested:
- Main working boat: to be used to change the nets, to maintain the mooring system, to harvest significant quantities of fish; it is usually a catamaran or a barge, equipped with a crane proportionate to the cage size.
- Feeding boat: to transport the feed on the cages, equipped with a feeding system, whenever absent on the cages.
- Auxiliary service boat: to transport the divers for the daily routines or to go quickly to the site whenever necessary.

Inland facilities

Any cage farm is equipped with a land base, usually located nearby the relevant harbour. Several facilities are connected to this base:
- A packaging area: here all the activities linked with grading, labelling and packaging are completed. Built in agreement with the European regulations to ensure the food safety, it is subjected to the release of a health authorization (EC number). Several controls by the local health board office are carried out during its activity. In this area, a cold store and an ice producer are always available; however, a fish size grading machine is present only rarely.
- A feed warehouse (or a silo storage system): to store the feed pallets periodically delivered by the suppliers; it is big enough to contain the feed required for at least one week in the peak consumption period.
- An area where the nets are stored and their maintenance is carried out: adequate to the net size and partially covered to avoid the UV negative action on the nylon fibres. Here (but also sometimes on the main workboat) the net washing machine, (useful and essential to clean the net quickly and satisfactory) is located.
- Offices and laboratory: depending on the size of the company, the laboratories are equipped with several instruments that allow a praecox identification to check the potential of diseases' outbreak. A minimum requirement is a microscope equipped with digital camera, a fridge to store the bacterial analysis kits and a basic laboratory equipment (glassware and stainless steel tools).

Stocking density and biomass balance

The stocking density is usually expressed in kilograms per cubic meter and depends on biomass and rearing volume. It is a parameter that must be kept under control as it is related to the welfare of the reared fish. The stocking density maximum value depends on several factors, inter alia the reared species, the health status of the batch, the size of the fish, the rearing system and the environmental conditions. To exceed these limits usually means to increase the risk of diseases and to decrease the growth performance.

Currently, for European seabass and Gilthead seabream reared in cages the value of 20 kg/m^3 is commonly applied, but production agreements between producers and wholesaler can fix lower values. A pilot project for the definition of a protocol for an organic aquaculture production has been carried out fixing the stocking density limit up to 10 kg/ m^3.

Especially for huge batches of fish stored in the cages for months, the update of biomass information of each cage is essential for a good management of the stock. It is always possible to check the average weight of the fish just by sampling the batch in the cage. To estimate the whole biomass we must know the number of fish at the moment of the sampling. An approximate quantification of the number of reared fish means to make several biomass-related errors which are negative for the economy of the company as well as for the surrounding environment; an overestimation of the biomass will imply overfeeding, which means an increase of feed waste in the site with ensuing negative impact on the environment and on the economic balance. On the other hand, an underestimation will imply a reduced amount of feed distribution with consequences from growth reduction up to stress-derived immuno-depression with potential disease outbreak. A correct estimation of the biomass will also allow to plan and assess the future production of the farm and to check the growth performance of the batches.

To reduce the risk of biomass errors it is essential that:

- the starting number of fingerlings will be quantified as accurately as possible;
- the uncontrolled output (escapes, thefts, predators, cannibalism) are minimized and
- that the controlled output (mortality, sample-movements, harvesting) is quantified and recorded.

Control of input

The initial number of the fingerlings can be quantified in different ways.

- Manual counting. After the fingerlings have been anaesthetized, they can be counted one by one. This method can be applied only for small batches. It is time consuming but exact.
- Automatic electronic counting. There are several adequate instruments, which are very expensive and usually not available at the hatcheries, also because an error of 3 percent by excess is supposed.
- Statistical estimate. This method is used mostly. It is based on the average weight of the fingerling and the biomass loaded in the means of transport. The fingerlings are fished and put into tanks filled with an exact amount of water. Each time a tank is full the net weight is calculated and recorded. In the meantime, several average weights are recorded during the whole loading operation. At the end of the procedure dividing the total of the net weights by the average weight will provide the total number of fish.

Uncontrolled output

The causes for loss of fish must be minimized as much as possible and in the cage systems the controls must be focused on:

- Accidental escapes. These may be drastically reduced through applying a plan of control and maintenance of nets and cages. The nets should be kept clean, by changing them or cleaning them with a high pressure cleaner, to avoid that the excess of fouling becomes too heavy, especially within rough sea, representing a potential cause of tearing. Where there are species that nibble the fouling on the nets, biting holes in them, major attention to the cage wall is required during inspections.

- Predators. They must be controlled. In Italy, the main predators on the open floating cages are birds, seagulls and cormorants; the only possible defense is to cover the cages with anti-birds nets. It could happen that an external predator fish (i.e. amberjack) is introduced during a batch transfer between cages, or that a cage is restocked while there still are "older" seabass. In these cases underwater fishing is the only solution.
- Cannibalism. It is a natural behaviour of some species of fish (i.e. seabass). It can be inhibited through homogenising the size of the fish. This can be achieved by a quality test of the fingerlings in the hatchery to avoid a too wide range of sizes in the batches and by a correct managing of the feeding.
- Surveillance. Human or video control, is always recommended to reduce the risk of thefts.

Controlled output

The output that can be easily quantified by just counting or estimating the number of fish:

- Mortality. Dead fish must be periodically removed from the cage, counted and disposed as special waste. The variation of the mortality trend will be an indicator of disease outbreak allowing immediate diagnosis and therapeutic response.
- Movements, sampling and harvesting. It is essential to record all the in–and–out–fish–movements for each batch and it is helpful to have a periodical stock report with the updated status of each cage.

Cages and environment

As mentioned before, in Italy the issuance of a license is subject to a prior environmental impact assessment, to be produced during in the initial phase, and, often, an EMP to be carried out during the activity of the farm. The results of the EMP shall be submitted to the local Environmental Office in charge of controlling the effective absence of significant pollution around the fish farm.

The main impacts on environment attributed to a fish farm are:

- Chemical pollution: avoid the use of antifouling copper-zinc based on the net and on the moorings components, reduce to the minimum any antibiotic treatment and do not treat with baths.
- Farmed fish escapes and interaction with the local species: the escaped fish, in addition to the economic damage, represent a risk for the environment. They could have predatory behaviour that, especially for massive escapes, represents a heavy unbalance in the prey/predator ratio of the surrounding ecosystems. They could also interbreed and/or compete for specific ecological niches with the local population of fish. Aspects of uncontrolled output as mentioned above should be considered in addition.
- Organic matter discharge around the cages: to reduce this kind of impact some recommendations should be followed:
  - cages should be located in an area with sufficient water renewal (current);
  - cages should be located in deep waters (a minimum of 20 metres of total depth);
  - cage depth should be not more than one-third of total water depth;
  - maximum water temperatures should not exceed 27 °C;
  - sediment below cages should be controlled regularly;
  - concession should allow moving cages from time to time into different positions;

- – use only high energy diets for reduced feed conversion rate;
- – feed with rationality (cease application of feeds once fish stop feeding, feed according to current, feed with the correct intensity, do not overfeed).
- Visual alteration on scenic places: cages could represent a serious problem if the site is near a coast of landscape interest and/or a touristic industry is developed. The choice of the cage model (i.e. submersible) will be essential to avoid negative interactions.
- Modification of natural current pathways: the preliminary project will have to consider this aspect, analysing the historical data available and assessing any potential risks related with the farm location.

DISEASE, CONTROL AND TREATMENTS

Cages are an open system which allows the exchange of pathogens between cultured and native fish, including the following risks:

- Transfer of potentially pathogenic organisms to the local fish population through escaped fingerlings.
- Exposition of reared fish to the local pathogens naturally present in the site.

Therefore, any introduction of fish must be strictly controlled to ensure the good health status of the fingerlings and the absence of pathogens potentially dangerous for the local species. Farming practices and conditions must be optimized to avoid the outbreak of local endemic diseases including:

- vaccination of fingerlings (whenever possible);
- control of stocking density to avoid cage overcharge;
- giving attention to the mortality trend;
- routine veterinary analysis and
- minimized livestock stress (reducing handling, feeding with a balanced diet, maintaining clean nets).

Seabass and seabream can be affected by several pathogens, viral, bacterial or parasitic. The Viral Encephalopathy and Retinopathy (VER) causes severe loss of seabass, mainly in batches under 100 grams. No treatments are available and the virulence can only be limited by increasing the quality of the rearing conditions. Seabream can be affected by the lynphocystis virus (Iridoviridae), which occurs mainly in the juveniles up to 50 grams; this cause skin lesions, but mortality is limited, and it mainly weak the fish and reduce the growth. Rearing conditions play a determinant role in controlling this disease. The two most relevant bacterial disease that can occur in caged seabass are vibriosis (which etiological agent is the *Vibrio anguillarum*) and the pasteurellosis (which etiological agent is *Photobacterium damselae* sub. *piscicida*). These infections can outbreak violently and, if not treated rapidly with Oxytetracycline or Flumequine, represent a risk of significant high losses of fish. *Flexibacer* spp. is one of the most frequent agent of seabass myxobacteriosis and it can be dangerous in poor environmental conditions, it is treated with Oxytetracycline or Amoxicillin.

One of the most pathogenic endoparasitic disease is the enteromyxosis, caused by *Enteromixum* (or *Mixidium*) *leei*, that can occur in some sparids, mainly the sharpsnout seabream and occasionally gilthead seabream. This protozoarian infection can cause severe loss of fish, not necessary concentrated in a short period but also with a stillicide mortality. No successful treatments are available yet. Ectoparasites of the order of Monogenea (mainly of the family Diplectanidae or Microcotilidae), are very common in caged fish; they are commonly attached to the gill arches and can injure the gill filaments but they are often secondary of a prior different infection, and could be considered not very relevant on an economic point of view.

In Italy, currently the use of only a few antibiotics, to be given orally, is authorized, and each treatment must be carried out under veterinary surveillance. Any treatment represents a source of pollution for the environment and must be carried out only if strictly necessary. In addition, the abuse of these substances carries the risk of bacterial strain drug resistance and consequently the risk of stronger, potentially uncontrollable infections in the future. Any kind of external bath to control the parasitic infections is not allowed.

REFERENCES

Beaz Paleo, J.D. & Muir, J. & Turner, R. 2000. Offshore mariculture: Workboats. *Mediterranean offshore mariculture.* Options Méditerranéennes. Série B. Etudes et Recherches; no. 30. Zaragoza. CIHEAM-IAMZ.

Beveridge, M. 1996. *Cage aquaculture*, 2nd edition. Fishing News Books, Oxford.

Brister, D.J. & Kapuscinski, A.R. 2000. Environmental Assessment Tool for Cage Aquaculture in the Great Lakes: An Overview. *Environmental Strategies for Aquaculture Symposium Proceedings*. 5-6 December 2000 in conjunction with the 62nd annual Midwest Fish and Wildlife conference in Minneapolis, MN (available on the Internet at http://www.idea.iastate.edu/aqua/pub03.pdf)

Department of Marketing & Institute of Aquaculture University of Stirling. 2004. Study of the market for aquaculture produced seabass and seabream species. Report to the European Commission DG Fisheries. Final report 23rd April 2004. (available on the Internet at http://europa.eu.int/comm/fisheries/doc_et_publ/liste_publi/studies/aquaculture_market_230404.pdf)

FISHSTAT Plus Universal software for fishery statistical time series. FAO Fisheries Department, Fishery Information, Data and Statistic Unit.

Landoli, C. 2000. Marine fish farming in Italy. *Mediterranean offshore mariculture.* Options Méditerranéennes. Série B. Etudes et Recherches; n. 30. Zaragoza. CIHEAM-IAMZ.

Panunzio, P. & Landoli, C. 1999. Legal aspect of aquaculture in Italy. In: *Aquaculture Planning in Mediterranean countries*. Options Méditerranéennes, Série Cahiers no. 43. Zaragoza. CIHEAM-IAMZ.

PIRSA, Primary Industries and Resources SA. 2000. *Marine Aquaculture Development Guidelines* (available on the Internet at http://www.pir.sa.gov.au/byteserve/aquaculture/species_profiles/marine_dev_guidelines_fs.pdf)

Scott, D.C.B. & Muir, J.F. (2000). Offshore cage systems: A practical overview. *Mediterranean offshore mariculture.* Options Méditerranéennes. Série B. Etudes et Recherches no. 30. Zaragoza, CIHEAM-IAMZ.

Staniford, D. 2002. Sea cage fish farming: an evaluation of environmental and public health aspects (the five fundamental flaws of sea cage fish farming). Paper presented at the European Parliament's Committee on Fisheries public hearing on Aquaculture in the European Union: Present Situation and Future Prospects', 1st October 2002 (available on the Internet at www.qccqld.org.au/savethebay/documents/ Euro_Paper_5_Fundamental_Flaws_of_Sea_Cage_Fish_Farming.pdf and www.seaweb.org/resources/sac/pdf/Staniford_Flaws_SeaCage.pdf)

The Scottish Association for Marine Science and Napier University. 2002. Review and Synthesis of the Environmental Impacts of Aquaculture (REIA) Scottish Executive Central Research Unit 2002 (available on the Internet at http://www.scotland.gov.uk/cru/kd01/green/reia.pdf)

Italian trade data source http://www.pesca.ismea.it/CommSel.asp

Primary drivers for cage culture and their relevance for African cage culture

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Rana, K. & Telfer, T. 2006. Primary drivers for cage culture and their relevance for African cage culture. In M. Halwart and J.F. Moehl (eds). *FAO Regional Technical Expert Workshop on Cage Culture in Africa. Entebbe, Uganda, 20–23 October 2004.* FAO Fisheries Proceedings. No. 6. Rome, FAO. pp. 99–107

ABSTRACT

Although the use of cages for holding and transporting fish for short periods is historic particularly in China, the development of modern cage culture for food production and ornamental purposes has evolved substantially in recent decades only, both in systems design and impact on total aquaculture production. This paper explores key drivers that have influenced cage culture in Europe and elsewhere to draw on lessons that may be of relevance to African cage culture development.

Conservative estimates suggest that around 3 million tonnes of fish are produced in cages notably in coastal environments, in Europe, the Americas and Asia. The drivers for the rapid uptake of cage culture have been largely technical, market driven and species' dependent, whereas the drivers affecting recent change to continued expansion and management are largely regulatory, both of which may have direct relevance for emerging cage farming in Africa. The direction and emphasis for African countries may depend on whether the products are intended for domestic or international markets.

The widespread uptake of cage farming has been driven by its relatively low cost compared with land based systems, versatility of material use and construction and perhaps more importantly easier access to open waterbodies. The flexibility and adaptability of cages for culture have enabled cages to be used for all stages of the product flow from breeding and seed production to final production for consumption. In addition to markets, the expansion of the subsector and its impact on production, however, has been primarily driven and facilitated by research and development in and assured availability of high quality of seed and feed, both of which are current constraints in sub-Saharan Africa. A modest 100 tonnes tilapia unit requires around half million fry and 150–200 tonnes of pelleted feed. Therefore, for any meaningful sectoral cage culture development in Africa priority should be given to addressing these drivers. Although set-up capital costs may be lower than land based operations, capital and operational costs can be high and therefore access to finances will also have to be considered.

Market forces have also been prominent in steering changes in cage farming. Decline in prices, traceability, biosecurity and public pressure have necessitated management changes and such lessons may be relevant to African countries.

The rapid expansion phase of cage culture in Europe and the Americas has been recently tempered by the potential for the nutrient inputs to approach the carrying

capacity of enclosed or partially enclosed farmed waterbodies. More recently in Europe, the new EU Water Directive aims to harmonize environmental regulations across the EU with respect to water quality standards, and may require the industry to adapt to enable future expansion. Lessons from these and other initiatives will be relevant to Africa. Whilst such emerging regulatory frameworks will vary for coastal and inland waterbodies, the primary drivers in each environment type will be influenced by competition for water by multiple users, selection of and benchmark tolerance levels set for indicators, skills and organization of environmental groups in influencing these processes. The infancy of cage farming in Africa does provide an ideal opportunity for countries to establish realistic baseline indices and indicators to facilitate and promote well-planned cage farm sites and management practices both in inland and coastal waters.

BACKDROP

The use of cages for holding and transporting fish for short periods is historic particularly in China. The development of modern intensive cage culture for food production and ornamental purposes, however, has evolved substantially since the 1960s, both in systems design and impact on total aquaculture production (Beveridge, 2004). This presentation explores key drivers that have influenced cage culture in Europe and elsewhere to draw on lessons that may be of relevance to African cage culture development. These drivers which could be internal or external, may have a positive or negative impact on cage culture development

Conservative estimates suggest that around 3 million tonnes of fish are produced in cages notably in coastal environments, in Europe, the Americas and Asia with species groups such as salmon, seabream and seabass, yellow tail tuna as well as groupers reared almost exclusively in cage systems. Cage farming for production purposes has two main strands of parallel development both of which are of relevance for African cage culture. Traditional cage farming systems and practices in Asia rely mainly on natural materials and inputs such as trash fish and biowastes. Such systems essentially consist of simple net bags suspended on staked timber or wooden structures linked to accommodation platforms of various kinds. Historically, in these environments people live on houseboats or over or very close to abundant water resources and such lifestyles have driven and helped evolve specific cage rearing practices. Its relevance to Africa may be site specific and limited to small-scale cage culture and may be ideally suited for decentralised seed production operations. Modern cage culture on the other hand using synthetic materials and floating devices of various construction and sophistication is a phenomenon since the 1960s and outputs from such systems has made a notable impact on total aquaculture production.

Provided the economic dynamics are conducive such cage culture operations can make significant impact on national and regional aquaculture production. In western markets, the tilapias, which are prime candidates for African cage culture, is competing with cod and haddock both of which are declining. The recent successful promotion of tilapia as a substitute has created increasing demand for tilapia as fresh and frozen fillets as well as whole fish in America and Europe.

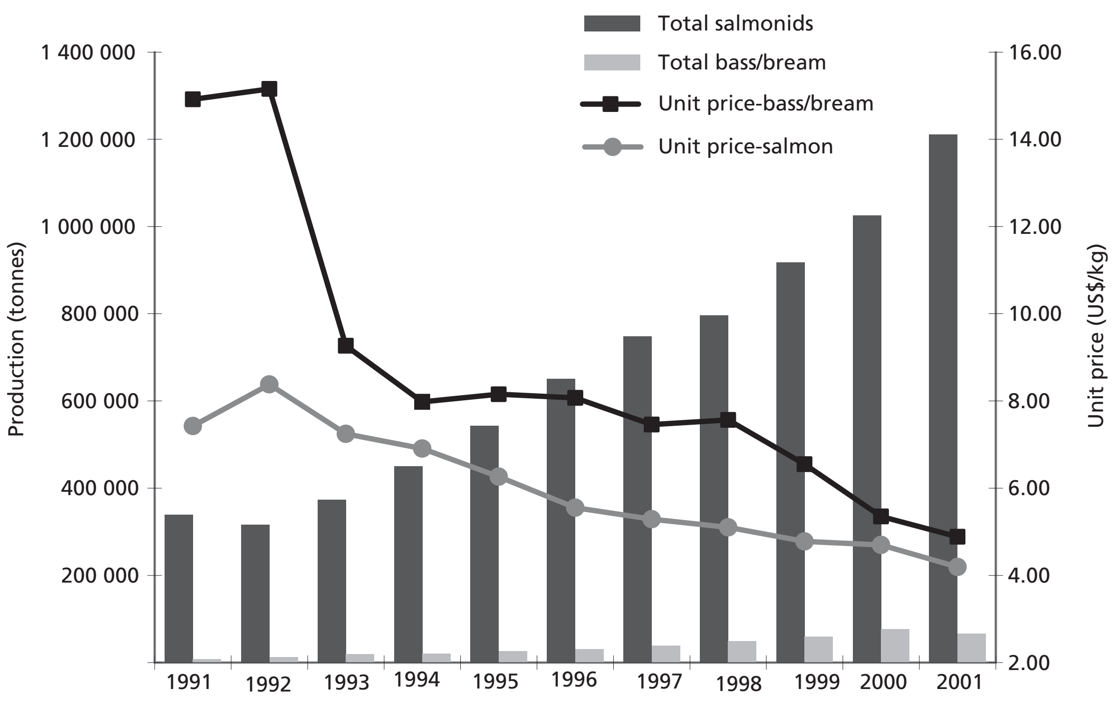
There are likely to be two broad divisions and approaches to cage culture development that may have drivers of different speeds. Cage farming driven by investment at an enterprise level which will be driven by internal assessment of markets, financial structures and technical inputs and those driven by government/regional/international bodies promoting cage farming development. The juxtapositions of these two interest groups will to a large extent influence the rate at which development can occur at national level.

MAJOR DRIVERS

Markets – export vs domestic

At the enterprise level the economic viability of such operations will largely be shaped

FIGURE 1
Temporal changes in production of salmonids and seabass/seabream and unit prices of salmon and seabass/seabream farmed in cages (data adapted from FAO, 2003).



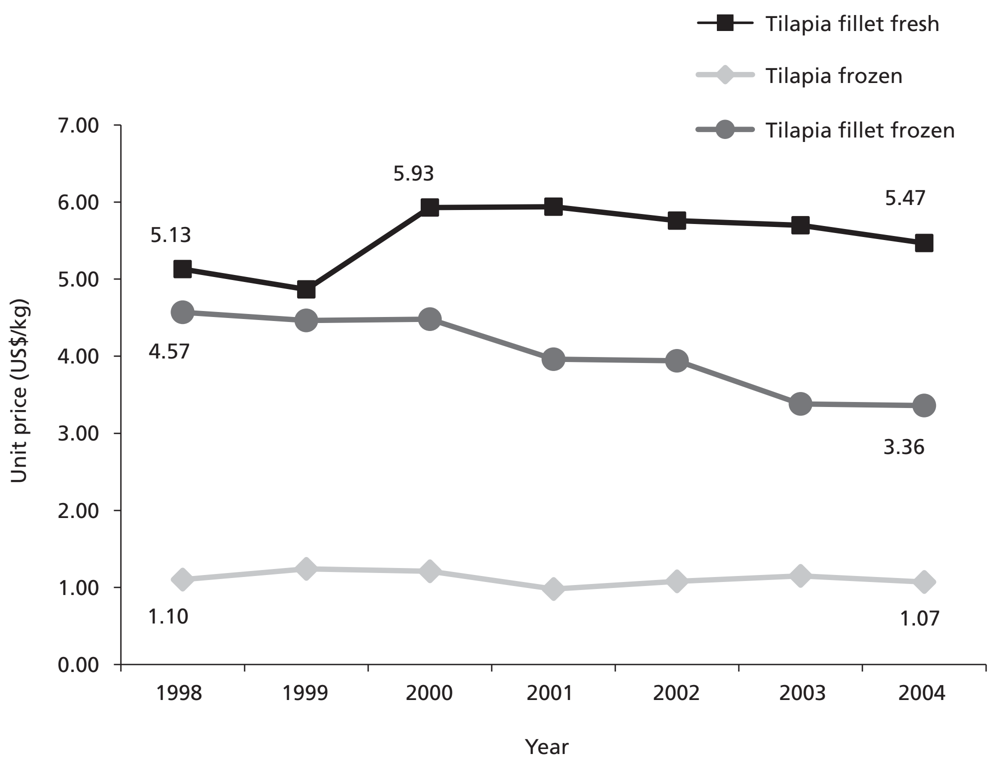
and driven by management capacity and production efficiency. In recent years, the salmonid and seabass industry has undergone substantial restructuring following increasing supplies and decreasing fish prices. This has resulted in larger vertically integrated companies often having cage sites in several countries. Potential investors in Africa should be mindful of the inevitable fall in prices accompanying significant increases of production and supply in the international markets. The extent of such interaction for salmon, seabass and seabream farmed in cages is shown in Figure 1.

The prices of tilapia products in the United States are given in Figure 2. This also points at the inevitable slide in prices. Cage operations targeting export markets will have to evaluate and build in plans for economies of scale and production efficiency measures to compete in the international market place.

At the global level, the relatively high price is driving investment opportunities in farming of tilapia for export. The relatively stable prices in United States (Figure 2) and higher prices in Europe (Figure 3) suggest an undersupply and opportunity. As already evident for frozen fillets these prices are likely to show inevitable signs of decline (Figure 2). Whilst these prices appear to be attractive to drive investment they should be viewed cautiously. Firstly, prices are for fillets and therefore assuming a filleting ratio of 35 percent the round weight equivalent for fresh fillets at US$5.50 is around US$1.90/kg. Secondly, because some of these data are derived from customs records they are, by definition, most likely "CIF" prices (cost, insurance, flight) and not "FOB" prices (free on board). Thus, for cage farming operations to achieve optimum returns and economic sustainability there is need for concerted efforts to maximize the use of the whole fish.

Akin to the salmon industry in Europe one parallel strategy for African countries is to actively explore the development of domestic markets. Available data suggest that the per caput fish consumption is decreasing (20 percent between 1990 and 1996) in many

FIGURE 2
Mean annual import price fluctuations of three main tilapia forms in USA (data adapted from American Tilapia Association, 2003).



African countries and the rate of urbanisation (7–10 percent/year) in many cities exceeds that in Asia. Establishing the significance of these national markets, where prices in real terms are likely to be higher, may offer appropriate incentives for driving small- and medium-scale cage culture closer to these markets. A recent study by Jagger and Pender (2001) on markets, marketing and production suggests that in many African cities fish supplies are not keeping pace with the growing demand; it provides an analysis of markets in Uganda concluding that the urban and peri-urban markets in Kampala and Jinga show greatest potential to sell fish to meet this growing demand for fish.

The choice of species and level of water quality can drive the level of intensity of cage production practices. Extensive cage culture is common in many eutrophic inland freshwaters; such an approach, as in China, could be used to reduce euthrophication (Beveridge, 2004). Semi-intensive operations are most common and the scale of such practices are driven by the availability of low cost feed inputs such as rice bran, spoilt grain, brewery wastes, domestic waste and seed (esp. wild seed). Such scenarios may be applicable in many African countries aiming to produce fish such as the tilapias that are low in the food chain and where feed inputs may be a constraint.

The applicability of such practice for tilapias however is not widespread (Beveridge, 2004). Investment driven ventures, however, engage in intensive cage farming operations often using high value species as candidates for culture. Intensive tilapia cage farming is practised in some countries and the products are principally intended for the European and United States' markets were they could fetch premium prices. At present, Zimbabwe is probably the only African country supplying around 300 tonnes of fresh-farmed tilapia fillets to EU (Figure 4). Whilst cage farming is probably still the most economical method for intensive aquafarming, capital costs are high; thus, economies of scale and investment levels will be paramount for driving success, not only for capital outlay but for operational costs.

FIGURE 3
Mean annual import price fluctuations for tilapia in Europe (Source: INFOnetwork Market Report. 2003).

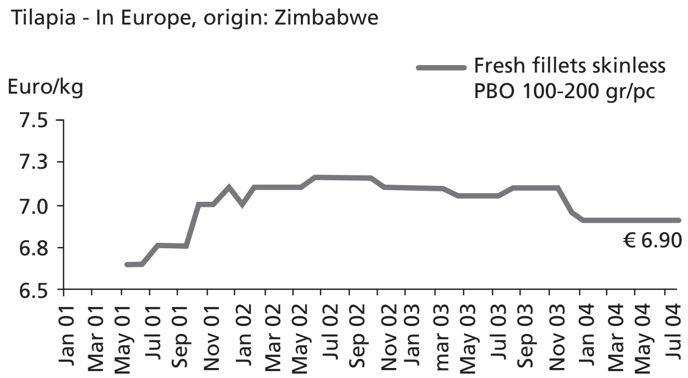
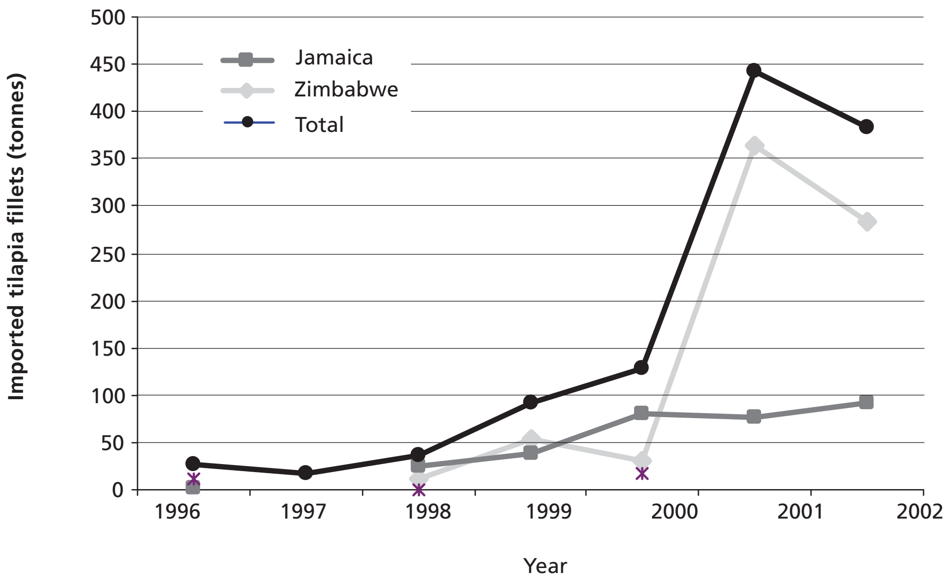


FIGURE 4
Imports of farmed fresh tilapia (fillets) into the European Union (data adapted from INFOnetwork Market Report. 2003).



Logistical and technical drivers

In addition to secured markets a key driver for uptake of cage farming in many developed countries is site availability, security and access. In Europe and North America much of these cage culture developments are coastal and the scale of fish farming, at least initially was driven by site availability. As cage farming is undertaken beyond the high watermark, farming is practised in open-access waterbodies although accesses to these waterbodies are required. Commonly, suitable waterbodies have to be leased or rented from the state. Similarly, cage farming in African countries does offer the potential opportunity especially for landless people to take up cage farming provided institutional mechanisms and processes are in place to oversee and enforce equitable economic development taking into account national poverty alleviation strategies.

For cage farming being undertaken in open-access waterbodies, the capacity to secure investment from human and animal larceny and the weather will have a significantly bearing on uptake and sustainability of cage operations. Attempts to introduce salmon cage farming in Western Cape in South Africa failed, because of persistent damage in these high-energy coastlines. These experiences had discouraged cage farming in South Africa. Bad site selection can therefore have a negative impact on uptake.

The availability of seed and feed of acceptable quality is a crucial technical driver, which must be addressed to promote African cage culture. Small-scale cage seed production operations may be a way forward to create employment and generate income for poorer entrants. Such operation can be initiated and supported by local government institutions with finance from agricultural and commercial banks. The scale of the task is not huge; the production of 1 000 tonnes may require around 5–10 million fry per year.

Whilst cage farming in African eutrophic waters will benefit aqua candidates lower in the food chain, intensive operations by definition will have to secure significant tonnage of artificial diets. The capacity to secure commercial diets will therefore require a constructive cooperation between potential government institutions, farm investors and local feed manufactures; this will be crucial for jump-starting and servicing cage farming. A modest development of 100 tonnes of intensively farmed tilapia will require 150–200 tonnes of feed.

The success of cage farming operations will be strongly influenced by the capacity to deliver products to target markets in the shortest time possible. Therefore, adequate roads, freight routes and costs will be crucial drivers for maintaining and increasing market share. If cage culture operations are targeting niche export markets the capacity of institutions and enterprises to meet sanitation and quality control standards are likely to determine the pace of uptake and market penetration.

SECTORAL DRIVERS

Regulatory drivers

The speed at which national cage culture is driven will also be influenced by regulatory mechanisms controlling development; it is likely to play a notable role in the rate of generating and maintaining interest in African cage culture as well. In Europe and the United States aquaculture development is highly precautionary and therefore heavily regulated. The rapid expansion phase of cage culture in Europe and the Americas has been recently tempered by the potential for the nutrient inputs to approach the carrying capacity of enclosed or partially enclosed farmed waterbodies and a precautionary approach has been adopted.

In countries like the United Kingdom, the process can be cumbersome and protracted. Many countries in Europe lack regulations tailored specifically for aquaculture or cage farming and therefore more generic statuary instruments may be used. In the United Kingdom there is a four stage process. A person seeking to establish a salmon (cage) farm requires consent to discharge effluents under the "Control of Pollution Act" from 1974. This is only considered after successfully seeking development consent and lease from the crown estate, marine works licence and navigational consent from the Scottish Executive Development Department. Moreover, expansion of the sector is now under the direction of the Policy "On regulation and expansion of caged fish farming of salmon in Scotland". In addition, successful application is conditional of operators submitting annual and independent environmental impact assessments (EIA) returns. In Scotland, which is over 90 percent compliant with all regulatory tools, the driving force of regulation is management of discharge of effluents by the statutory bodies. For cages being in intimate contact with the aquatic environment, the discharge is readily (ideally) diffused and therefore less manageable. In Scotland, incentives are being offered to companies to move cage operations onshore so that their single point discharge can be controlled, monitored and regulated more closely. Small-scale freshwater cage farming operations are also being moved on to land to allow ensure better compliance.

The capacity to regulate, however, will depend on the ability to monitor and police such activities. In African countries the capacity to police fish farming activities may be limited and therefore the value of regulation will need to be carefully and practically formulated if there is a desire to promote the subsector.

In this regard it is worth considering the environments that are proposed for cage culture in Africa and the central premise for its monitoring, using current rationale and models. The current interest is in developing cage culture in freshwater environments, e.g. rift valley lakes and small inland waterbodies. In freshwater bodies in Europe most of these waterbodies are/were oligothrophic and the primary aim of regulation is to minimize eutrophication. Clearly, other criteria are also important especially for marine environments; in the EU this includes the "Dangerous substances Directive (76/464/EEC)" and the "Paris Convention 1974 (PARCOM)", which recommend the limitation of fish density in cages, the avoidance of prophylactic use of chemicals, management agreements between neighbouring fish farms concerning the use of high quality stock, disease prevention, coordination, fallowing periods to allow the recovery of benthic areas as well as washing or drying of nets instead of using antifouling compounds.

Most models aiming at establishing pollution limits in freshwaters are concerned with eutrophication. A primary consideration of environmental impact is the phosphorous level, which is considered to be a limiting factor for primary production. It is therefore worth assessing the current situation in a few targeted waterbodies to establish scientific baseline indices and indicators against which any realistic cage farming impacts can be measured or any required regulation formulated. Inland waters have been classified according to their phosphorus levels; a Scottish Environmental Protection Agency tolerance level is 10 mg/m^3, the threshold between oligo- and mesothrophic waters.

In Africa, however, many waterbodies, including Lakes Victoria and Tanganyika, are already in an advanced state of euthrophication, and remedial measures to reduce phosphorus levels are unrealistic. Recent studies on water quality for land and water use in Winam Gulf of Lake Victoria reveal phosphorus levels in the range of 2–38 mg/m^3 and conclude that eutrophication is a major threat to Lake Victoria. In Lake Chivero phosphorus increased from 40 mg/m^3 in the 1960s to over 870 mg/m^3 in the early 1990s (Marshall, 1997). This is also supported by high nitrates levels and chlorophyll levels. Therefore, against this backdrop the value of regulation based on current models should be carefully evaluated. Perhaps more importantly the effect of eutrophication on dissolved oxygen (DO) and related toxin levels in these freshwater bodies needs to be given higher priority if economic failures are to be minimized to encourage uptake.

Recent studies in Lake Victoria for example suggest that anoxic depth has risen by 20 metres in 30 years, thus increasing the frequency and severity of fish kills during upwelling. Siting of farms therefore should be a prime technical driver to minimize economic losses and potential failure. For cage farms being directly immersed in the aquatic environment compared with land based systems they have (unfairly) attracted much more attention as polluters than other users of the resource. Several studies in Europe and Africa (Calamari *et al.,* 1997) have suggested that agriculture, industry and urban conurbations are significantly larger polluters. Results of a case study for Winnam Gulf, Lake Victoria in Kenya are given in Table 1 on next page. This study suggests that urban and agricultural activity, in particular livestock, are the main contributors to eutrophication in this area of Lake Victoria. In recent years cage farming in Europe and America has received negative publicity, because cage farming was targeted as a major polluter of environment.

TABLE 1
Estimated contribution of human activity to physio-chemical loading of Winnam Gulf, Lake Victoria (data adapted from Calamari *et al.,* 1997)

Activity	Tonnes/day			
	Refuse/ solid wastes	Sewage	BOD[1] load	Nutrients TP[2]
Urban loading (Kisumu)	74	4.5	6.4	
Industrial loading:				
Sugar industries	4.5		7	
Brewery	3		3	
Agrochemical	14		14	
Agriculture				3.3
Total (tonnes/day)	95.5	4.5	30.4	3.3

[1] Biochemical Oxygen Demand
[2] Total Phosphorus

Therefore, any attempt to further cage culture in Africa will have to promote such activities as ecofriendly.

It has now been acknowledged by the EU that water is not a commercial product like any other but rather a heritage, which must be protected, defended and treated as such. The EU has therefore established a new "Water Directive" in 2000, which establishes river basins as the basic unit of water resource management, and acknowledges that urbanization, industrialization and agriculture all have a significant impact on the deterioration of water quality. Its scope is also wide and charges members to protect surface waterbodies, groundwater bodies, transitional waters and coastal waters. In this regard, new initiatives introduced within the EU take a more holistic view of water use and aim to harmonize environmental regulations across the EU with respect to water quality standards; for the first time they acknowledge that agriculture and industry require adaptation to enable future expansion. In addition, another benefit of the framework directive approach is that it will rationalize the community's water legislation by replacing seven of the earlier directives: those on surface water, two directives related to measurement methods, sampling frequencies and information exchange on freshwater quality; the fish water, shellfish water and groundwater directives as well as the directive on dangerous substances discharges. The operative provisions of these directives will be taken over in the framework directive, allowing them to be repealed thereby streamlining regulation.

Such developments are of direct relevance as they allow the regulation of cage farming to be placed into context. This includes the "Urban wastewater treatment Directive", providing for secondary (biological) wastewater treatment and even more stringent treatment where necessary; the "Nitrates Directive", addressing water pollution by nitrates from agriculture; a new "Drinking-water Directive", reviewing the quality standards and, where necessary, tightening them (adopted November 1998) and a "Directive for integrated pollution and prevention control (IPPC)", adopted in 1996, addressing pollution from large industrial installations. To constructively drive African cage culture, we therefore need to be adequately prepared to place the environmental impact of cage culture in the context with other users.

SOCIAL DRIVERS

Waterbodies used for cage culture are also used by other users for capture fisheries, navigation, recreation and domestic purposes. Developing cage farming on such waters will require careful consideration of these uses through appropriate consultation to minimize conflicts that can arise especially with local fishermen who consider such areas as their fishing grounds. Such potential conflicts can delay uptake and frustrate development and investment. In this regard, zoning of water surfaces may be useful to resolve conflicts.

Incentives for uptake of small-scale cage culture activities by unemployed and vocationally trained young people could be a potent driver to stimulate seed production for ongrowing in cages. Local institutions can achieve this by providing targeted practical training for new entrants.

SUMMARY

Cage farming has made a significant production and economic contribution to aquaculture. The scale and sophistication of development varies globally and the versatility of cages has enabled them to be used for breeding through to ongrowing.

Internationally, the key drivers for cage farming are probably the economic opportunities presented to potential investors of various sizes and public, regulatory pressure on operators to be more accountable. Locally, a key driver is the necessity for poor rural people to derive food and income from the immediate environment by empirically harnessing their ingenuity and local materials. In Europe and America development of industrial-scale cage culture was also driven by assessments that showed intensive cage systems to be most economical, and availability of suitable sites fostered technology and expansion. For intensive cage culture in Africa, the challenges may not be as much the technical but more the required inward investments together with a conductive economic, political and regulatory environment. In considering the regulatory framework, the perceived impact of cage farming on the aquatic environment and other activities should be realistically taking into account the current status of waterbodies in relation to impacts from other users of these environmental services. Clearly, technical drivers such as availability of seed and feed as well as construction are essential for production but these can be sourced with careful planning and could drive small-scale cage culture activities and secondary opportunities. It will be shortsighted if African cage culture looks primarily to serve the export market. The development of strong local and regional markets must be considered in parallel if the subsector is to develop and expand responsibly.

REFERENCES

American Tilapia Association. 2003. http://ag.arizona.edu/azaqua/ista/markets.htm

Beveridge, M. 2004. *Cage aquaculture*. 3rd edition, Oxford, Blackwell Publishing 376 pp.

Calamari, D., Aketch, M.O. & Ochumba, P.B.O. 1997. Preliminary risk assessment of pollution of Winam Gulf, Lake Victoria, Kenya. In Remane, K., ed. *African inland fisheries, aquaculture and the environment*, pp. 351–376. Oxford, Fishing News Books. 464 pp.

FAO. 2003. FISHSTAT Plus: Universal Software for Fisheries Statistical Time Series. http://www.fao.org/fi/statist/fisoft/fishplus.asp

INFOnetwork Market Report. 2003. Globefish. FAO, Rome. http://www.eurofish.dk/indexSub.php?id=3031

Jagger, P. & Pender, J. 2001. Markets, marketing and production – issues for aquaculture in East Africa: the case of Uganda. Naga – The ICLARM Quarterly, 24(1&2): 42–51.

Marshall, B.E. 1997. Eutrophication in African lakes and its impacts on fisheries. In Remane, K., ed. *African inland fisheries*, aquaculture and the environment, pp. 166–174. Oxford, Fishing News Books. 464 pp.

Cage fish farming of tilapia in Zimbabwe – Lake Harvest Aquaculture (Pvt) Ltd.

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Located on Lake Kariba in northern Zimbabwe, Lake Harvest grows tilapia (Oreochromis niloticus), which was introduced to the environs of Lake Kariba some twenty years ago for the purpose of fish farming.

Lake Kariba is a man-made reservoir about 270 km long, with Victoria Falls near one end and the Kariba Dam (hydroelectric power) at the other. It is in a national park that has no industry and few people, high quality freshwater and good temperatures for growing tilapia all year round.

Lake Harvest has pioneered the technology for rearing tilapia commercially in offshore net cages. The production cycle takes about fifteen months from egg to market size (750 g whole fish) and the maximum stocking densities at harvest are around 40 kg per cubic metre. We breed and grow juvenile fish in fifteen hectares of earthen ponds near Kariba Town. Around two million fry per month are produced using natural breeding techniques and immediately androgenised over 21 days in purpose-built tanks. The fry are grown on to 25 g in earthen ponds before transfer to the offshore cages after three months. Lake Harvest has not had to treat its fish for any disease condition since start-up in 1997.

Fingerlings are transferred to cages in live fish transport tanks. The journey takes around two hours. They first go into juvenile cages and are grown up to 80 g plus before cage splitting and transfer to “production cages”. The fish spend a total of around 12 months on the lake. The cages are plastic circles, modified from the European design for salmon. The plastic circles give good flexibility in rough conditions but have their drawbacks too (e.g. need for boats for most operations). The cages and nets are built by Lake Harvest but the plastic pipes and net panels are imported. The moorings are robust and designed to withstand high seas, which are not unusual on Lake Kariba. Each site has 14 cages, each equipped with a production net, predator net and bird net.

Feed is made in Zimbabwe to Lake Harvest’s specifications. Floating extruded feed has proved being important for cage aquaculture of tilapia in Lake Harvest’s experience.

Once the fish reach market size they are harvested live and brought in daily for swift processing in Lake Harvest’s purpose-built factory, which is also located in Kariba Town. Only tilapia fish farmed by Lake Harvest as described above are processed in the factory.

Lake Harvest's main product line is fresh chilled skinless boneless fillets for export to Europe. We also produce frozen fillets and whole fish for the regional and local markets, where demand is increasing. By-products are either sold fresh for human consumption through the factory's "Fish Shop" (heads and belly-flaps), or are sold to local crocodile farmers (skins, scales, guts, pin-bones and frames) as a high quality fresh feed ingredient.

The Nile perch *Lates niloticus*: a potential candidate for cage aquaculture

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Trials carried out at the Kajjansi Aquaculture Research and Development Centre, in a range of pond, tank and net systems, suggested that the Nile perch (*Lates niloticus*) has considerable potential for aquaculture, the most promising results being obtained from raising them in trash fish fed net cages sited in ponds.

Growth trials in small 4.5 cubic metre cages, using wild caught Nile perch juveniles stocked at ten fish per cubic metre and fed on the small fresh fish, *Rastrineobola argentea* (known locally as "*mukene*") resulted in exponential growth from 10 to 550g in seven months. The Nile perch's feeding response to trash fish was highest in the hour before sunset and following short periods of heavy rain. Food conversion ratios from 4:1 to 8:1 were recorded during the trials.

No mortalities (nor incidences of cannibalism) were recorded and the Nile perch in the trials did not appear overly sensitive to low dissolved oxygen levels or regular handling and sampling. A number of the fish developed skin lesions, possibly resulting from ectoparasitic infections.

The work carried out suggests that the Region's small-scale fishermen could diversify their livelihoods and generate useful income through this technology. The case for this was strengthened considerably by the finding that fishermen unintentionally catch large numbers of juvenile Nile perch whilst night fishing for mukene.

Further research efforts should proceed as follows:

1. piloting the basic cage culture technology with fishing communities;
2. improving trash fish feeding strategies;
3. developing techniques for the artificial propagation of seed; and
4. developing techniques for weaning juveniles onto artificial diets.

FAO Regional Technical Expert Workshop on

Cage Culture in Africa

20–23 October 2004
Entebbe, Uganda

This document contains the proceedings of an FAO Regional Technical Expert Workshop on Cage Culture in Africa, held in Entebbe, Uganda, from 20 to 23 October 2004. The workshop was attended by 71 participants including regional participants from the public and private sectors, resource persons from Italy, Norway, Thailand, the United Kingdom of Great Britain and Northern Ireland, and Zimbabwe, observers, the FAO Technical Secretariat and support staff. The workshop was unanimous in concluding that cage aquaculture represents an important development opportunity for many African countries, but will require an effective policy framework to ensure that structural constraints to development are overcome, and that development is equitable and sustainable. Successful development of cage aquaculture will depend on many factors. The challenge for both government and the private sector is to work together to address these issues.

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