DRAFT Report
This study is commissioned by ICSF

Aquaculture and its Genetic Resources: Corporations versus Communities

Can Small Scale Fishing Communities benefit from Current Developments?

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December 2009

International Collective in Support of Fishworkers
(ICSF)
www.icsf.net
2009

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1 Introduction

Give a man a fish, and you feed him for a day.
Teach him how to fish and he will feed himself for the rest of his life.

This proverb encapsulates the guiding principle to development cooperation of the last century. But such an approach overlooks that fishing communities – including the women among them - usually know their art anyway. Knowledge and education are still important today but not enough on their own to assure survive in a time when resources are no longer easily accessible. Resources in the oceans are increasingly depleted and difficult to access, but not for lack of knowledge of fishery communities. Given the current circumstances, must small-scale fishers and smallholders in developing countries need to cultivate fish to survive?

It is predicted that aquaculture production will soon overtake the stagnating capture from the wild. Aquaculture growth is strongly led by developing countries, and smallholders in China and most other Asian countries have increased their production by between five and ten percent annually over the past decades. In the North, aquaculture is growing at a far slower rate.

Many governments and mainstream development organisations seem intent on industrialising aquaculture, and to promote export oriented aquaculture activities in the South. Such an approach has many implications for thriving Asian smallholder aquaculture, and on smallholders in Latin America and Africa.

The present study was commissioned by the International Collective for the Support of Fishworkers (ICSF), an international NGO supporting small-scale fishworkers, whose mission is "to support fishing communities and fishworker organizations, and empower them to participate in fisheries from a perspective of decent work, equity, gender-justice, self-reliance and sustainability."

ICSF's expressed interest in industrial aquaculture and its development is from the perspective of communities whose lives and livelihoods depend on activities related to small-scale and artisanal fishing, and small-scale aquaculture. ICSF is interested to understand how developments in the aquaculture sector could affect the social, economic, cultural, and political rights of these communities, particularly their rights to life and livelihood.

Industrial aquaculture is increasingly competing with smallholders for resources, like freshwater, land, coastal areas or marine organisms. Increased use of pelagic fish for feeding in industrial aquaculture is a case in point, as is the destruction of mangroves for industrial shrimp cultivation. Smallholder resources can also be affected by chemical pollution originating from industrial aquaculture, or spreading of pests and diseases from aquaculture to wild aquatic populations, or genetic contamination of wild populations. Exotic species that escape from industrial aquaculture can have unforeseeable impacts on ecosystems. In addition, smallholder aquaculture is increasingly integrated into industrial value chains, which are established to provide large markets, particularly for export. Such integration can involve fundamental changes in smallholder production systems, including the use of industrial inputs like feed, veterinary treatment and breeding lines. The growing near shore and off-shore mariculture production is however, not a particular focus of the study.

The terms of reference for the report are to:

- Document, comment on and analyse key developments in aquaculture and the potential implications for small-scale fisheries and fishing communities, with particular focus on the aquaculture genetics industry and gene technology;
- Identify specific campaign points that can be taken up by small-scale fishworker groups to defend their interests.

Following this introduction, Chapter Two and Three describe and analyse smallholder aquaculture, and global statistical trends, from a critical perspective. Chapter Four gives an overview on a small sector of aquaculture, industrialised aquaculture, with some detail on the relevant main groups of species, salmon, shrimp, tilapia, and catfish. Chapter Five is focusing on the corporatization of aquaculture seed sources, which has different features in Asia, Latin America, Africa, and the industrialized countries. This chapter includes descriptions of prominent aquaculture genetics companies. Chapter Six provides information on biotechnology developments in aquaculture, and Chapter Seven describes the proprietary arrangements the genetics companies are making to prevent their customers from reproducing the animals, while Chapter Eight discusses some aspects of intellectual property and access to genetic resources in aquaculture. The concluding Chapter Nine intends to outline what may follow from this report.

The challenge was to compile and analyse the trends from the perspective of their possible impact on smallholders, which in several aspects was not available before. Since biotechnology companies not only learn from each other but also merge to become multi-species genetics corporations, there may be lessons to learn from the parallel experience available from the plant and livestock biotechnology developments.

2 Smallholder aquaculture

A definition of small-scale fisheries and aquaculture

A group of experts participating in the FAO Working Group on Small-Scale Fisheries (Bangkok, Thailand, November 2003) described the sector on the basis of the range of characteristics likely to be found in any particular small-scale fishery.[1] Small-scale fisheries can be broadly characterized as a dynamic and evolving sector employing labour intensive harvesting, processing and distribution technologies to exploit marine and inland water fishery resources. The activities of this sub-sector, conducted full-time or part-time, or just seasonally, are often targeted on supplying fish and fishery products to local and domestic markets, and for subsistence consumption. Export-oriented production, however, has increased in many small-scale fisheries during the last one to two decades because of greater market integration and globalization. Small-scale fisheries operate at widely differing organizational levels ranging from self-employed single operators through informal micro-enterprises to formal sector businesses.

Similarly, smallholder aquaculture is varied with regard to social organization, employment, as well as a wide array of technologies, knowledge, species, and feed. Access to land and water bodies can be a major challenge. Smallholder aquaculture caters to subsistence or to local, regional, national or export markets. In some cases, processors or traders have integrated smallholders in contract production.

Nutritious food of most of the world's poor

Fish are highly nutritious, rich in micronutrients, minerals, essential fatty acids and proteins. They provide essential nutrients and have particular importance in natal and child health and development. They provide more than 2.6 billion people in developing countries with at least one fifth of their animal protein intake.[2] Bangladeshis get 63% of their animal protein from fish, as do 58% of Indonesians, and the figure rises to 75% in Cambodia.[3] However, in many Asian societies, most of protein requirements are met by plant sources. The populations depend on fish for the essential nutrients (amino acids, fatty acids, and minerals) not provided by their other foods.

Fish is an essential part of the diets of most of the world's poor, especially in Asia. Data on its cost compared to livestock products is hard to come by. This is due in part to the wide variety of fish species, and the range of prices for different products. One of the most important determining factors is the perishability of fish, which is more pronounced for oily or pelagic species (herrings, mackerels, sardines etc) compared to white fish or demersal species (cods, groupers, snappers etc). White fish tends to command the highest prices, with the notable exception of sashimi grade tuna, whilst oily fish is of relatively low economic value. In developing countries, small pelagic fish often represent an important food resource of the poor. Even in developing countries like India, the growing urban retail market and increased production cost is making fish less and less affordable to the poor.

In Europe, fish products from both wild and aquaculture production often cost several times more than meat products. In the case of aquaculture, they are expensive because their production is expensive, with some of the main species (salmon, trout and shrimp) being carnivorous. They need feed that is rich in omega 3-fatty acids (present in fish oil) and rich in

[1] FAO (2005): Increasing the Contribution of Small-Scale Fisheries to Poverty Alleviation and Food Security, Technical Guidelines for Responsible Fisheries 10
[2] FAO (2006): The State of World Fisheries and Aquaculture; and FAO (2007) State of World Aquaculture 2006.
[3] Worldfish: Fish, Food and Energy: balancing our approaches to meeting growing demand http://www.iclarm.org/v2/FishFoodEnergy.html (accessed 7/10/2009)

protein. In the main such feeds are derived from the industrial reduction of fish (although protein from fishmeal is increasingly replaced by protein from other sources), which in turn is based mainly on small pelagic species. Increased feed demands from the aquaculture industry has boosted fishmeal prices and associated carnivorous aquaculture costs. From the global perspective, such fish are net fish protein reducers, requiring 3 or more kilograms of fish for every kilogram of fish produced. Fattening of bluefin tuna needs up to 20 kg of fresh fish to obtain 1 kg tuna growth.

This is in contrast to aquaculture for some local markets in developing countries where fish feed on mainly on plankton, aquatic plants, or a range of items provided by waste recycling or natural production in the pond. However, shrimp aquaculture also depends on fish meal, and other aquaculture systems in developing countries, like for tilipia and pangasius (which although not fishmeal and fish oil dependant) increasingly use industrial feeds and have even triggered a "trash fish" feed fishery, raising serious environmental concerns. .

High diversity of aquaculture production systems and genetics

"Aquaculture takes place in fresh-, brackish- and marine waters; in lakes, rivers, reservoirs, farm ponds, rice fields, lagoons, coastal waters and the open sea. Production systems range from natural, modified or artificial systems, to semi-intensive aquaculture systems and intensive ponds, pens, cages, tanks and other containments." To this comprehensive description, even more elements, like greenhouses, or power station effluents, could be added. According to the FAO Commission on Genetic Resources,[4] "Approximately 236 species of fish, invertebrates and plants were farmed in 2004."[5] Smallholders are raising a large variety of species in a large variety of production systems. Their systems have been developed to suit local environmental, cultural and social circumstances. Secure rights (both tenure and access) to land and water are an essential prerequisite for sustainable and viable aquaculture.

Integrated aquaculture and polyculture

An often cited model of sustainable smallholder aquaculture is polyculture in China and other Asian countries, and especially the dike-pond system in the Pearl River Delta.[6] The system uses several carp species that feed at different trophic levels: The herbivorous grass carp, the filter feeding bighead and silver carps, the detritus feeding mud carp, and the omnivorous common and crucian carps, so that feed niches are well used and an excess of feed (eutrophication) is avoided. In the Pearl River Delta, wetlands were reclaimed by digging ponds and using the excavated soil to raise elevated dikes on which fruit and vegetables were raised, including mulberry bushes to provide leaves to feed silk worms which supported the silk industry of southern China. It was also characterized by integration with other local human activity systems besides plant crops and used inputs, both on and off-farm, from animal husbandry, sanitation and cottage-level industries such as silk and soybean processing wastes. While this system, known since the 14th century, succumbed to the high land prices due to a Special Economic Zone established in the area,[7] comparable integrated pond systems are pervasive in other parts of China and Asia.

In Viet Nam, for example, the small-scale, integrated farming system known as VAC combines three different farming components. These are: vegetable or fruit garden (*vuon*),

[4] FAO Commission on Genetic Resources for Food and Agriculture (June 2007): The world's aquatic genetic resources: Status and needs, Rome
[5] FAO (2006) The State of World Fisheries and Aquaculture; and FAO (2007) State of World Aquaculture 2006.
[6] Ruddle, K. and G. Zhong1(988): Integrated Agriculture-Aquaculture in South China: the Dike-Pond System of the Zhujiang Delta. Cambridge University Press, Cambridge
[7] Peter Edwards (2008): From integrated carp polyculture to intensive monoculture in the Pearl River Delta, South China Aquaculture Asia Magazine Vol. XIII, No. 2 April-June 2008
http://library.enaca.org/AquacultureAsia/Articles/april-june-2008/1-peter-edwards-april-08.pdf (acc. 7/10/2009)

fish/shrimp pond (*ao*) and livestock pen (*chuong*). VAC is the most common freshwater technology in Viet Nam, especially in the northern and Mekong Delta regions.[8] The integration is so widespread and successful, economically as well as environmentally, that efforts are made to integrate industrial livestock farming with fish ponds and gardening.[9]

In South Asia, vegetables may also be grown in ponds,[10] and ponds and rice fields are commonly fertilized with cow or buffalo dung, not only to grow rice, but also water fowl and fish. FAO states that "the rich aquatic biodiversity of some Asian rice field ecosystems provides over 100 species of aquatic plants and animals of use to humans."[11] Polyculture is also practised in the Philippines, notably where the herbivorous milkfish is grown together with the carnivorous prawn.

A comparatively small quantity of industrial feed is used, according to a study of six Asian countries.[12]

On the West coast of India, the age old shrimp filtration practice, in Kerala known as 'chemmeen kettu', is carried out after the harvest of paddy. Shrimp and fish seeds brought in through tidal water are trapped in the fields and are allowed to grow for 4 to 5 months. In this traditional system no selective stocking and supplementary feeding are done.[13] What makes the prawn culture attractive is its organic character. Prawns in such fields subsist on organic matter from decayed stubble, drying waterweeds etc and are not fed with chemical feed. In turn, the rice fields are enriched in manure and the excreta of organic wastes from fish and prawns.[14]

Hatching the diversity

The rearing of aquatic species in a sustainable manner has accumulated knowledge and experience that has been developed over the millennia. A large number of species have been domesticated around the globe since hundreds of years, and some of them since several thousand years. Aquaculture is at least a 4-5000 year old human activity, as recorded from China (2800 B.C.) and Egypt (2052–1786 B.C., Middle Kingdom).[15] The first how to do description, "The Classic of Fish Culture", was written around 500 B.C., by Fan Lai in China.[16] Under Mao Zedong, production was expanded 50-fold with the building of new water bodies. In the middle of last century, hypophysation, a hormone induced spawning method spread from China to other parts of the world, so that aquaculture could be practiced independent of wild habitats.

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[8] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia

[9] Vincent Porphyre, Nguyen Que Coi (eds.) (2006): Pig Production Development, Animal Waste Management and Environment Protection. A Case Study in Thai Binh Province, Northern Vietnam, CIRAD

[10] R. N. Mandal, G. S. Saha, P. Kalita, and P.K. Mukhopadhya (2008): Ipomoea aquatica – an aquaculture friendly macrophyte. In: Aquaculture Asia Magazine Vol. XIII, No. 2 April-June 2008

[11] FAO Commission on Genetic Resources for Food and Agriculture (June 2007): The world's aquatic genetic resources: Status and needs, Rome

[12] M.R. Hasan (ed.) (2007): Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper. No. 505. Rome

[13] Aquaculture: Engineering the Blue Revolution. In: Samudra, May 1998; G.Harikumar,, G.Rajendran (2007) An Over View of Kerala Fisheries – with Particular Emphasis on Aquaculture, http://www.ifpkochi.nic.in/IFPS2.pdf (accessed 7/10/2009)

[14] K. T. Thomson (2003) Economic and Social Management of Estuarine Biodiversity in the West Coast of India. Indira Gandhi Institute for Development Research, Mumbai, India

[15] G.J.Jessé & A.A.Casey (An Ongoing Study For The Charity, Commenced In 1978): Study of the Chronological Dates In World Aquaculture (Water Farming) History From 2800 B.C., World of Water, UK.

[16] Herminio R. Rabanal (1988): History of Aquaculture. ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Manila, Philippines (ASEAN/SF/88/Tech. 7) http://www.fao.org/docrep/field/009/ag158e/ag158e00.htm

Nowadays, in most countries and most species, the trend is for juveniles not to be collected from the wild, but multiplied in hatcheries or produced by the farmers themselves. According to WorldFish Center, most smallholders in China, and a part of the Vietnamese smallholders produce fingerlings themselves.[17] Brian comments: include in recommendations?FAO found in several Asian countries that some 60 species were multiplied in hatcheries.[18] The local hatcheries often produce several species together, and as such are well adapted to multi-species ponds, or polyculture. Some seed is imported, and a few species, such as eel and some new cultured species, are being captured from the wild.[19]

Collecting juveniles from the wild is considered harmful to the environment because small meshed nets are used, by catch and associated discard levels may be high, especially where the stocks are reduced. On the other hand it is necessary to avoid inbreeding. Too narrow genetic relation may result in genetic defects.. A large number of independent hatcheries and protected areas for wild populations would be an ideal way to avoid genetic losses. Genetics companies have developed their own methods to avoid inbreeding, basically separate containers for separate populations, and carefully managed breeding. Biotechnology is also used to recognize levels of inbreeding.[20] Domestic stocks may be refreshed with collections from the wild.

Smallholder groups contract hatcheries for quality seed

Seed quality also includes health and other criteria, and in the absence of certification, smallholders find it difficult to procure good quality seed from hatcheries. In India, groups of smallholder shrimp farmers, “Aquaclubs”, collectively place a bulk order to a hatchery, well in advance of the planned stocking date, for production of required quantity and quality of seeds. Through a consultative process, a mutual agreement is formed between selected hatcheries and Aquaclubs, including transparent control by farmers’ representatives.[1] Arun Padiyar, NACA (2005): Shrimp : Contract hatchery systems: A practical approach to procure quality shrimp seed for small-scale farmers in India. http://www.enaca.org/modules/news/article.php?storyid=624

In China, a public training and extension system is disseminating the knowledge of how to maintain the seed quality of independent hatcheries. Such a system is well established in China but needs upgrading in many other countries, according to WorldFish.[21] Also, a seed certification system is recommended by several studies. Only fragments of aquaculture seed certification systems exist in a few Asian countries (Indonesia, India, China, Philippines,

[17] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p

[18] Counted from Tab. 6.2.2. in Siriwardena, S. N. 2007. Freshwater fish seed resources and supply: Asia regional synthesis, pp. 59–90. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p

[19] Honglang, Hu. 2007. Freshwater fish seed resources in China. pp. 185–199. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p

[20] Mair, G.C. 2007. Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p.

[21] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p.

Thailand).[22] Certification and up grading may have implications for the small-holders and smaller scale production units, and their control over the production process and this needs to be taken into account.

Local feed use

The WorldFish Centre notes that several fish species need no external feeds, and produce good harvests relying solely on manure, kitchen waste, leaves, and crop residues.[23] This however, depends on scale and intensity of the production system, as well as on the mix of species. FAO recently underlined the "multi trophic aquaculture (growing fish, molluscs and seaweeds together in the same environment) as an efficient opportunity to increase fish supplies.[24] Peri-urban aquaculture benefits from the use of local wastes, while a wide range of polyculture and integrated agriculture-aquaculture systems (for example, fish in association with rice, cattle, pigs, or ducks) offer feed options for rural areas.[25]

A World Bank study[26] recommends to focus on local feed resources and to

- identify locally available waste products for their feed potential and
- develop simple and cost-effective methods of increasing their nutritional value
- Support the adaptation of low-cost processing machinery and improve methods of
- processing and storing farm-made aqua-feeds
- Support the setting of standards and monitoring of aqua-feeds for the presence of GMO ingredients and contaminants such as mercury or PCBs, and for provision of advice and monitoring of feed additives such as probiotics
- Review incentive systems for artificial feed production, such as the removal of tariffs on the import of key ingredients for mills producing fish feeds
- Support the introduction, where land availability permits, of integrated production systems using wastes and natural feeds.

But the expansion of industrial scale feed mills in developing countries is continuing. Cargill Inc., the world's largest grain trader and processor, in 2006 opened an aquaculture feed factory in Viet Nam with a capacity of 60,000 tonnes, more than the combined capacities of the local feed companies.[27] The following year, Cargill Inc. was overtaken by several other multinational feed operators, the largest being CP Feed Mills, subsidiary of the largest Asian food processor Charoen Pokphand.[28]

Smallholders in developing countries increasingly use compound feed. For example, in Viet Nam, pangasius hatcheries feed fingerlings with 30-45% fishmeal. The outgrowers use trash fish.[29] Almost all the pangasius is exported.

A comparative study of feed economics of several hundred farmers in six Asian countries showed that in Chinese farms, industrially manufactured feeds accounted for 75 percent of

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[22] Siriwardena, S. N. 2007. Freshwater fish seed resources and supply: Asia regional synthesis, pp. 59–90. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p

[23] Worldfish: Fish, Food and Energy: balancing our approaches to meeting growing demand http://www.iclarm.org/v2/FishFoodEnergy.html (accessed 7/10/2009)

[24] FAO Committee on Fisheries Sub-Committee On Aquaculture Fourth Session Puerto Varas, Chile, 6 - 10 October 2008: Opportunities for Addressing the Challenges in Meeting the Rising Global Demand for Food Fish from Aquaculture

[25] The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington

[26] ibid.

[27] USDA Vietnam Fishery Products Annual Report 2007 http://www.fas.usda.gov/gainfiles/200707/146291702.pdf (accessed 7/10/2009)

[28] http://www.feedindustrynetwork.com/ViewArticle.aspx?id=27054 (accessed 7/10/2009)

[29] Le Nguyen Doan Khoi (October 2007): Description of the Pangasius value chain in Vietnam. CAS Discussion paper No 56 http://webh01.ua.ac.be/cas/PDF/CAS56.pdf (accessed 7/10/2009)

the total feed consumption. In aquaculture farms in Bangladesh and the Philippines, respectively, industrial feeds accounted for 54 and 49 percent of total feed consumption. In Thailand, and Viet Nam, industrial feeds accounted for 35 percent of the total while India was the least user at only 31 percent. In terms of absolute volume of industrially manufactured feed utilization however, Viet Nam and Thailand were the largest users while the Philippines and India used the smallest quantities. The field work was carried out in 2005.[30]

The high cost limited the use of compound feed. In Viet Nam, for example, home made feed was USD 0,18/kg, while manufactured pelleted feed cost was USD 0,34/kg. Feed conversion ratio was 2,35 in pellets, and 3,06 in farm-made feed. The market price of pangasius was USD 0,66/kg for pellet fed fish, and USD 0,54/kg for traditionally fed pangasius. Net returns per ha of land, per labour day, or per capital input were better in traditional farms that produced their own feed.

Development of feed based on low-cost locally produced ingredients would help improve farmer's low profit margins, recommended the above mentioned study.[31]

In the Philippines, tilapia farmers are trained by local government on how to reduce the use of commercial feeds. Larvae simply feed on plankton and do not thrive well on artificial feeds. The supply of plankton in the pond, with right fertilization, is abundant at the early stages of the culture period. Delaying commercial feed by 45 days would reduce feed cost significantly, is the recommendation.[32]

Do export oriented farmers favour compound feed, and local market oriented farmers prefer the cheaper home made feed? The answer may often depend on how much farmers earn from production for export or for local markets. In some instances in export oriented aquaculture, farmers may be required to use industrial feed. Or, they may be provided with a package of inputs from the exporters, including feed.

Particularly in Vietnam, where pangasius is produced for export,

- Similar net returns were recorded by farms using home-made feeds and those using a mix of home-made and industrial feed. . The intensive farms received the highest gross return but a lower net return as compared to the other two farming types.
- Net returns to labour, land and capital were highest in traditional farms.

However, farm-made feed is gradually being replaced by manufactured pelleted feed or a combination of farm-made and manufactured pelleted feeds because of the reduced supply and increased price of feed ingredients for formulating farm-made feed.[33]

The already cited FAO study (give reference – FAO 2007, Fisheries Technical Paper No 505?) concludes that there is no indication that commercial feed improved the benefit cost ratio. It did in Thailand and the Philippines but not in Bangladesh and Viet Nam, where farms using home-made feed had the best benefit cost ratio.[34]

It appears that due to lower cost of farm made feed, the farmers produce less output, but earn more. Ingredients for home made feed are however, under pressure of an increased

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[30] M.R. Hasan (ed.). Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper. No. 505. Rome, FAO. 2007
[31] ibid.
[32] Philippine Business Mirror, December 30, 2008
[33] Phuong, N.T., Sinh, L.X., Thinh, N.Q., Chau, H.H., Anh, C.T. and Hau, N.M. (2007). Economics of aquaculture feeding practices: Viet Nam. In M.R. Hasan (ed.). Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper. No. 505. Rome, FAO. 2007. pp. 183–205.
[34] M.R. Hasan (ed.). Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper. No. 505. Rome, FAO. 2007

production, mainly for export (Not clear what the point is here… the ingredients are under pressure, or the system of using home-made feeds in under pressure).

The market prices for their produce play a vital role, and in Viet Nam, aquaculture farmers were operating not far above the break even, while the situation was better in the other countries studied.[35]

Industrial feed vs home made feed

	Home-made feed	Industrial feed
Ecological footprint	Believed to be low, local ingredients, waste recycling,	Believed to be high due to transport energy, fishmeal and fish oil use, feed grain grown with high chemical input
Food web	Herbivores are fed without animal proteins – Not sure what is at issue here	provides animal proteins to herbivores – Not sure what is at issue here.
Feed conversion rate[36]	High	Low (feed composition adjusted to need); From a low feed conversion ratio, a high environmental sustainability is often concluded without considering footprint
Standard quality of feed	Variable but importance not pivotal	pivotal where growing conditions are standardized
Genetically modified ingredients	Not common	Common[37]
Labour intensity[38]	Believed to be high, but data are inconclusive	Believed to be low but data are inconclusive
Price[39]	Low (incl. labour cost)	high

Labour intensity of feeding – many open questions
To prepare fish feed at the farm requires work. Farmers in Bangladesh, India, and Viet Nam use relatively less supplementary feed and fewer other inputs than farmers in China and Thailand. However, data available on labour intensity of feeding are not very conclusive. The cited FAO study on feed cost[40] presents data according to which

- in Bangladesh,[41] China,[42] and Vietnam,[43] labour cost in farms using home made feed were lower than in farms where industrially manufactured feed was used.
- In Thailand,[44] labour cost for feeding was lowest in traditional systems; traditional systems had high labour cost for excavation of ponds, and this led to the conclusion that traditional farms had the highest labour cost.
- In the Philippines,[45] labour cost related to feeding were lowest in traditional systems, while cost for watchmen were highest in traditional systems, so the total labour cost

[35] ibid FAO 2007, Fisheries Technical Paper No 505?
[36] ibid.
[37] according to the market leader, Nutreco/Skretting http://www.skretting.com.au/Internet/SkrettingAustralia/webInternet.nsf/wPrId/322EA2230AD1DCA3CA25745E002512DF?OpenDocument (accessed 7/10/2009)
[38] M.R. Hasan (ed.). Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper. No. 505. Rome, FAO. 2007
[39] ibid.
[40] ibid.
[41] ibid., p 50
[42] ibid., p 82
[43] ibid., p 191
[44] ibid., p 170 and 171

were highest in traditional systems. It is remarked that watchmen fulfill other tasks as well, including feed preparation and collection of feeds, from which follows that feed related labour cost is unclear.

In all cases, unpaid labour was monetised (is this the correct term?) and included in the calculations.[46]

More comparative data are needed with regard to labour input for feeding.

Environmental services: Waste treatment, disease control, and more
Since potential ecosystem services of aquaculture are so far hardly used by industrial aquaculture, they are rarely considered or form a part of standards. These less known services of traditional aquaculture include sewage[47] and other solid waste processing, waste water recycling, and disease control, among others:

- In open water bodies, fish eat a number of parasite hosts like mosquito larvae and snails. This considerably reduces the risk of transmission of tropical diseases like malaria, filariasis, yellow fever, river blindness, dengue fever, worm parasites, among others.

- Aquatic plants, shellfish, crustaceans, and fish can use different nutrients from solid waste and waste water. In Calcutta, it was possible to convince local authorities to cancel plans of modern sewage plants. They would have taken away the resources from which some 8000 aquaculture farmers in the bheris, i.e. local ponds, are producing 13,000 tonnes of fish annually. [48]
  The World Health Organisation has developed guidelines for the safe use of such resources in aquaculture.[49]
  The recommended system for waste water treatment in developing countries, provided that land is available at reasonable cost, is the stabilization pond system. This consists of a series of shallow man-made lagoons with the earlier ponds (anaerobic and facultative ponds) in the series loaded with waste water at too high a rate for fish to survive due mainly to oxygen depletion during the night. Fish culture can take place in later ponds in the series (maturation ponds) which are aerobic and function principally in pathogen removal. However, the production in these ponds may be low because most of the nutrients will have been removed from the water in earlier ponds in the series. The nutrient concentration reaching the maturation ponds may not be enough for adequate natural feed production for fish.[50]

- The rice field in Asia with their aquatic species are known for their pest management contribution.

- Unwanted water plants in irrigation channels can be controlled by some fish species, e.g. grass carp.

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[45] ibid., p 139 and 141
[46] ibid., p 18
[47] see http://www.fao.org/docrep/005/AD002E/AD002E02.htm#sec2 on "The Use of Sewage in Aquaculture" (accessed 7/10/2009)
[48] The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington
[49] WHO (2006c). WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Vol. III, Wastewater and Excreta in Aquaculture, WHO/UNEP, http://www.susana.org/images/documents/07-cap-dev/a-material-topic-wg/wg05/who-guidelines-3-2006-wastewater-in-aquaculture-en.pdf (accessed 7/10/2009)
[50] Edwards, P. 1990. Environmental issues in integrated agriculture-aquaculture and waste water-fed fish culture systems. Conference on environment and third world aquaculture development, Rockefeller Foundation, Bellagio, Italy, 17–22 September 1990.

The World Bank estimated that the ecosystem services of aquaculture could be as important as food production. The two roles could complement each other, if waste nutrients are transformed into food. A precondition is however, that wastes from industry and from domestic use are collected separately.[51]

But the bottom line is that aquaculture itself needs a clean environment.[52]

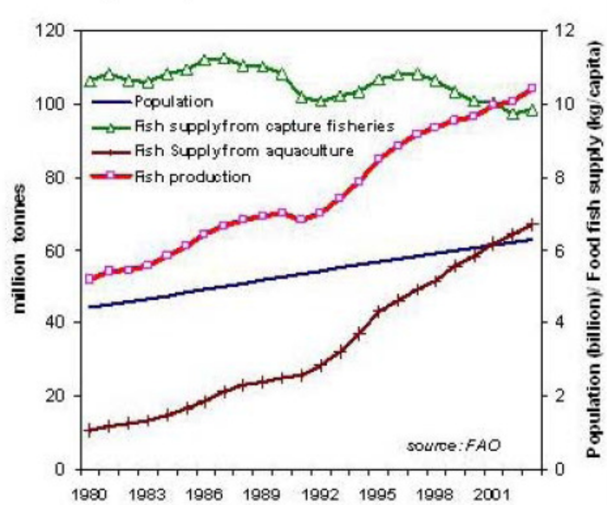
[51] Brian Halweil (2008): Farming Fish for the Future. Worldwatch Report 176, Washington
[52] The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington

3 Aquaculture development: Driven by the South

Aquaculture is the fastest growing agricultural industry, especially in China
Aquaculture is the most rapidly growing segment of the agricultural sector: While agriculture is growing at 2 to 3 per cent per year, aquaculture has been growing at an average of 8,8 percent per year[53] since 1970. Growth in China was more than 10 percent, compared with 7.0 percent in the rest of the world.[54] The contribution of aquaculture to world fish production has grown from 3.9% in 1970 to about 35% and this growth is continuing, while the fishery harvest from the oceans has not increased since 1990.[55]

The volume of farmed fish has accelerated growth so fast that projections when it would bypass the wild fish volume were in 2008 corrected to 2010,[56] while only five years earlier it was predicted to happen by 2030![57] In China, however, three quarters of the country's food fish comes from aquaculture, compared with just 20 percent for the rest of the world.

Figure 1. Global Population and Fish Food Supply from Fish Capture and Culture
Source: FAO, various years.



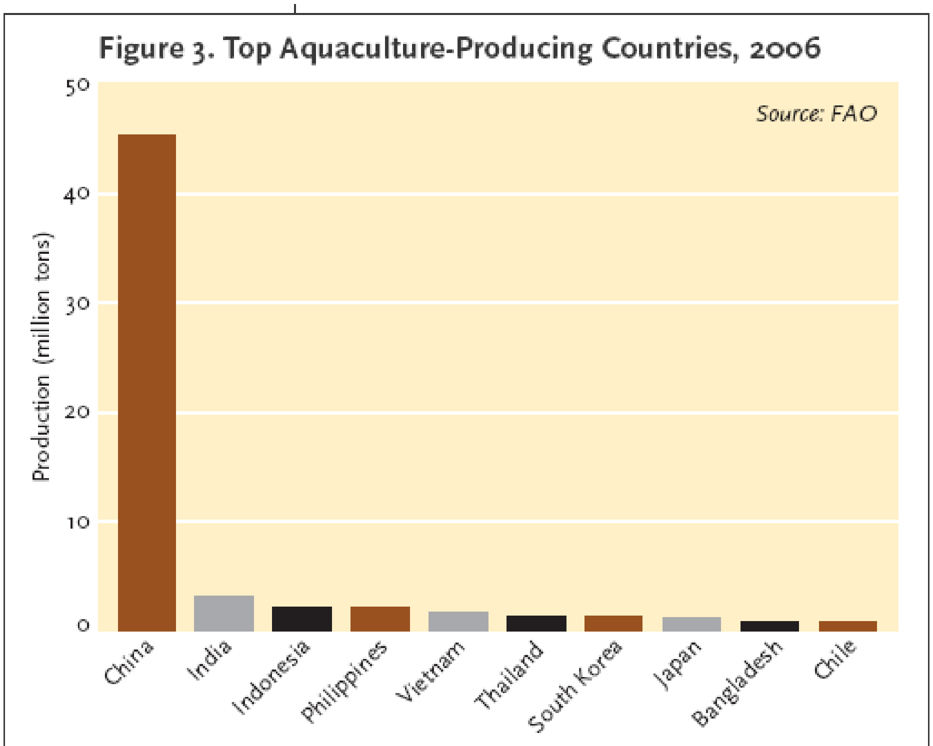
Source: The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington

A major reason for the growth of aquaculture probably is the development of aquaculture in China during the second half of the 20th century. More than three quarters of the country's

[53] The World Bank reports 10 percent in: The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington;
[54] FAO (2007) State of World Fisheries and Aquaculture 2006, Rome
[55] FAO (2006) The State of World Fisheries and Aquaculture and FAO (2007) State of World Aquaculture 2006. The FAO data on production in China have, however been corrected. Following this revision, world capture and world aquaculture fishery productions in 2006 are now 2.4 million tonnes and 3.3 million tonnes lower than previously reported, respectively. (FAO Food Outlook November 2008)
[56] FAO Committee on Fisheries, Sub-Committee on Aquaculture, Fourth Session: Opportunities for Addressing the Challenges in Meeting the Rising Global Demand for Food Fish From Aquaculture. Puerto Varas, Chile, 6 - 10 October 2008
[57] Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S. and M. Ahmed 2003. "Fish to 2020: Supply and Demand in Changing Global Markets." International Food Policy Research Institute, Washington, DC, and WorldFish Center, Penang, Malaysia.

food fish comes from aquaculture, compared with just 20 percent for the rest of the world.[58] In North America and Japan, aquaculture accounts for a minor portion of fish supplies, whereas in Europe it provides about 20 percent.[59]
Another probable reason is the depletion of the oceans. The majority of the world's most valuable fish stocks are either fully, or overexploited,[60] or their population sizes are fluctuating due to climate and related environmental changes. FAO points especially at reduced fish stocks of groundfish resources, but also at reduced anchoveta catches in Peru.[61]

Consumption increases mainly in China
Increasing consumption of fish is another major reason for the growth of aquaculture. While consumption is slowly increasing in the US and some European and Asian countries, but decreasing in Japan, the absolute bulk of consumption increase is taking place in China:[62] Consumption of fish per person in China has risen from less than 5 kg in the 1970s to the present 26 kg, around double the average world consumption level. Excluding China, average world consumption per person is ranging around 13 to 14 kg per person without dramatic changes since the 1970s.[63] Fish consumption is also increasing along with increases in human population, and aquaculture production is being promoted to meet production shortfalls from wild sources.



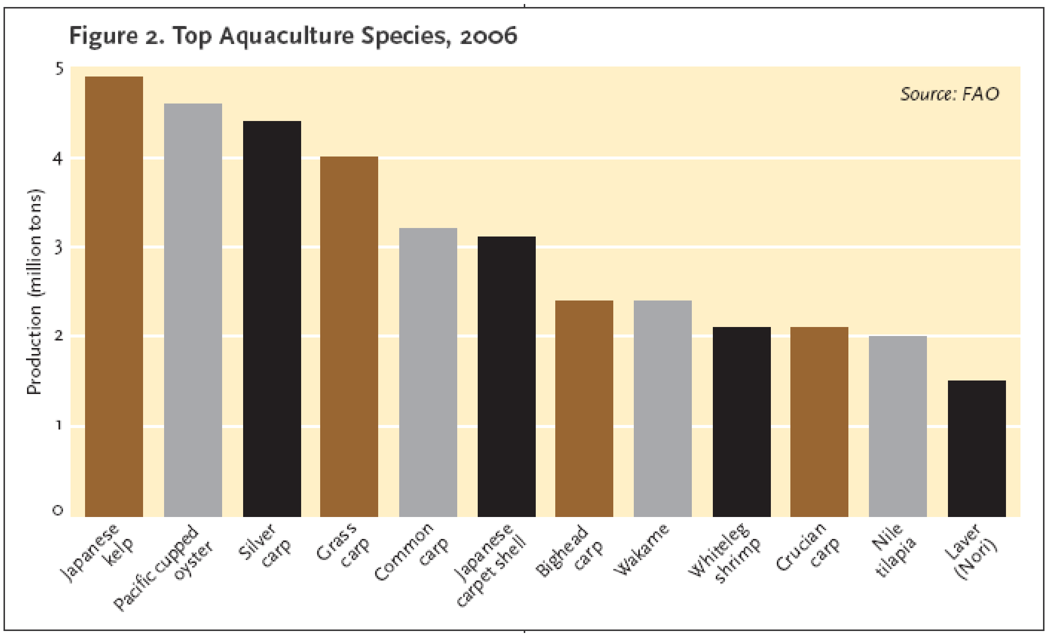
Source: Brian Halweil (2008): Farming Fish for the Future. Worldwatch Report 176, Washington

Production increases in smallholder aquaculture, and in China

[58] FISHSTAT data, cited after Brian Halweil (2008): Farming Fish for the Future. Worldwatch Report 176, Washington
[59] FAO (2009): The State of World Fisheries and Aquaculture 2008
[60] World Bank (2008): Sunken Billions: The Economic Justification for Fisheries Reform, Washington
[61] FAO Food Outlook June 2008
[62] According to FAO Food Outlook November 2008, China has for the first time, covered fisheries and aquaculture sectors in its National Agricultural Census. Therefore, some data may be subject to changes.
[63] FAO Food Outlook June 2008 http://www.fao.org/docrep/010/ai466e/ai466e10.htm (accessed 7/10/2009)

80 percent of the world's production of fish and fishery products takes place in developing countries.[64] FAO statistics record that 97 percent of freshwater aquaculture production (27.8 million tonnes in 2005) comes from the developing world, mainly Asia.[65] Over the decade 1997-2006, the share of industrialized countries in total production fell from 28 percent to just above 20 percent.[66]

China accounts for nearly 70 percent of the quantity and over half the global value of aquaculture production.[67] In 2007, the total value of aquaculture products reached 14.46 billion US$ and a volume of 6.528 million tonnes.[68] Today, according to WorldFish Center, efficiency in smallholder aquaculture in China is far higher than in most of the rest of Asia.[69]



Source: FAO, cited after Brian Halweil (2008): Farming Fish for the Future. Worldwatch Report 176, Washington

Main farmed aquatic plants and animals

Aquatic plants occupy a large space in aquaculture, and three plants are among the twelve most cultivated aquatic species. Among the aquatic animals, the Pacific cupped oyster with 4,5 million tonnes reached the highest global production, according to FAO 2004 data. Production of carps far exceeded that for all other finfish.

[64] FAO Food Outlook June 2008 http://www.fao.org/docrep/010/ai466e/ai466e10.htm (accessed 7/10/2009)
[65] Mair, G.C. 2007. Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p.
[66] FAO Food Outlook June 2008
[67] FAO (2006) *The State of World Fisheries and Aquaculture*; and FAO (2007) State of World Aquaculture 2006.
[68] Guo Yunfen (2008): International trade in Chinese aquaculture products: - Constraints and challenges http://library.enaca.org/certification/beijing08/draft_beijing_report_25-05-08.pdf (accessed 7/10/2009)
[69] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p.

With the exception of marine shrimp, the bulk of aquaculture production within developing countries comprises aquatic plants, omnivorous/herbivorous fish or filter-feeding species.
In contrast, the majority of aquaculture production in developed countries was of carnivorous finfish species.

Which species from where?

Production within each region is diverse. In the ***Asia and the Pacific*** region, aquaculture production from China, South Asia and most of Southeast Asia consists primarily of carps, while production from the rest of East Asia consists of high-value marine species. In global terms, some 99 percent of cultured aquatic plants, 98 percent of carps, 87 percent of shrimp and 93 percent of oysters come from Asia and the Pacific.

Meanwhile, 57 percent of farmed salmon and trout come from Western ***Europe***, mainly the northern part of the continent. However, carps dominate in the Central and Eastern European regions.

In ***North America***, channel catfish is the top aquaculture species in the USA, while Atlantic and Pacific salmon dominate in Canada.

In ***Latin America and the Caribbean***, over the past decade, salmon had overtaken shrimp as the top aquaculture species following disease outbreaks in major shrimp-producing areas and rapid growth in salmon production in Chile – but Chilean salmon production is currently down due largely to viral (Infectious Salmon Anaemia) and salmon lice infections.

The ***sub-Saharan Africa*** region continues to be a minor player in aquaculture despite its natural potential. Even aquaculture of tilapia, which is native to the continent, has not developed significantly. Nigeria leads in the region, with reported production of 44 000 tonnes of catfish, tilapia and other freshwater fishes.
In the *Near East and North Africa*, Egypt is by far the dominant country in terms of production (providing 92 percent of the regional total) and is now the second biggest tilapia producer after China and the world's top producer of mullets.

Source: Adapted from FAO (2006) The State of World Fisheries and Aquaculture

More fishers and female fish workers

The strong expansion of aquaculture activities during the past three decades comes along with a significant increase of fishers and fish farmers. Their numbers have grown faster than the world's population, and faster than employment in other agricultural sectors. In 2006, an estimated 43,5 million people worked as fishers and fish farmers, the great majority of these in developing countries, principally in Asia.[70] The numbers engaged in fishing and aquaculture in most industrialized economies have been declining or stagnating. In 2004, fish farmers accounted for one-quarter of the total number of fish workers. China is by far the country with the highest number of fishers and fish farmers, reported to be 13 million in 2004, representing about 30 percent of the world total.[71] FAO estimates that about 5.8 million fishers (about 20 per cent of the total) can be considered poor, earning less than US$ 1 per day.[72]

According to ICSF, the figures are likely to be underestimated, as millions of people fishing are seasonally or part-time, in coastal and inland waters, and are not recorded as fishers. ICSF estimates that an additional more than 100 million people are employed in other occupations associated to fisheries. Small-scale fisheries, and this includes aquaculture, are often the main drivers in the rural economy, with important forward and backward linkages.[73] Women play an important role in smallholder aquaculture in most Asian countries. They attend to fish ponds, feed and harvest fish, and collect prawn larvae and fish fingerlings. However, women's most important role in both artisanal and industrial fisheries is at the processing and marketing stages. In some countries, women have become important entrepreneurs in fish processing; in fact, most fish processing is performed by women, either in their own cottage-level industries or as wage labourers in the large-scale processing industry.[74]

Fish processing factories have hardly improved women's status: Viet Nam ranks eighth in the world for fish and aquaculture exports. According to the Ministry of Agriculture and Rural Development, fisheries in Viet Nam supply work for millions of coastal farmers, 50 per cent of them women. However, 85 per cent of workers in seafood processing factories are women, and "they seldom receive a high salary or chance of promotion as men do. Female labourers in small-scale fisheries and aquaculture have to work very hard, but their effort isn't recognised by their own families or the community."[75]
Conditions of work in aquaculture farms as well as safety of aquaculture workers in different forms of aquaculture including seaweed farming, mariculture, shrimp and salmon farming and other forms of aquaculture should be jointly analysed by FAO and ILO, demanded ICSF in its statement to the FAO Committee on Fisheries in March 2007.[76]

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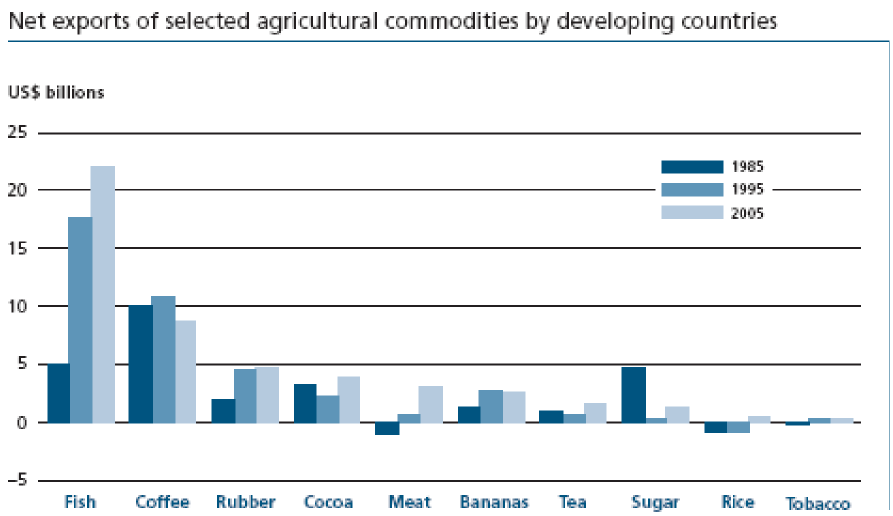
[70] FAO (2009): The State of World Fisheries and Aquaculture 2008, Rome
[71] FAO (2006): The State of World Fisheries and Aquaculture; and FAO (2007) State of World Aquaculture 2006.
[72] Chandrika Sharma and Ramya Rajagopalan (2006): Allocation of Fisheries Resources: A Small-scale Fisheries Perspective, Presentation to the 'Sharing the Fish – Allocation Issues in Fisheries Management' meeting, www.icsf.net/jsp/ www.fishallocation.com (accessed 7/10/2009)
[73] ibid.
[74] FAO (2007) State of World Aquaculture 2006
[75] Southeast Asia Fish for Justice (SEAFish) and Marinelife Conservation and Community Development (MCD) Press release 03-12-2008 http://www.mcdvietnam.org/?page=article_detail&id=1110&category_id=155 **(accessed 7/10/2009)**
[76] Statement by the International Collective in Support of Fishworkers to the Twenty-seventh Session of the Committee on Fisheries, March 2007

Fish from developing countries: the world's most traded agricultural commodity

The fisheries and aquaculture sector contribution to Gross Domestic Product (GDP) typically ranges from around 0.5 to 2.5 percent, but may exceed 7 percent in some countries, which often compares very significantly with the crop/livestock sector GDP.[77] Not only the domestic economy contribution is substantial; current export earnings in developing countries from seafood are pivotal.[78]



Source: FAO (2009): The State of World Fisheries and Aquaculture 2008

Fish is by far the most traded primary food product. 37 percent of world aquatic production quantity is traded internationally.[79] In comparison, for meat products, the figure stands at 9 percent. The value of fish trade is expected to soon bypass USD 100 billion,[80] certainly depending on the financial crisis and its duration. 50 percent of the traded products are from developing countries. Here the net export revenue of US$25 billion (exports minus imports),[81] is approximately as high as all other developing countries' food exports combined.

The South provides aquatic feed and food to the North

In developing countries, there is considerable growth in export-oriented aquaculture, which is a driving force for investment by large corporations in large production units, feed mills, by pharmaceutical companies, and other players. The involvement of these players in the aquaculture sector is the cause of increasing competition for access to and ownership of aquatic resources, including in coastal areas, and a potential threat to the livelihood rights of small fishing communities and to small-holder fish farmers.

77 FAO (2008): Climate Change for Fisheries and Aquaculture. Technical Background Document from the Expert Consultation Held on 7 to 9 April 2008, Rome

78 FAO Food Outlook June 2008 http://www.fao.org/docrep/010/ai466e/ai466e10.htm (accessed 7/10/2009)

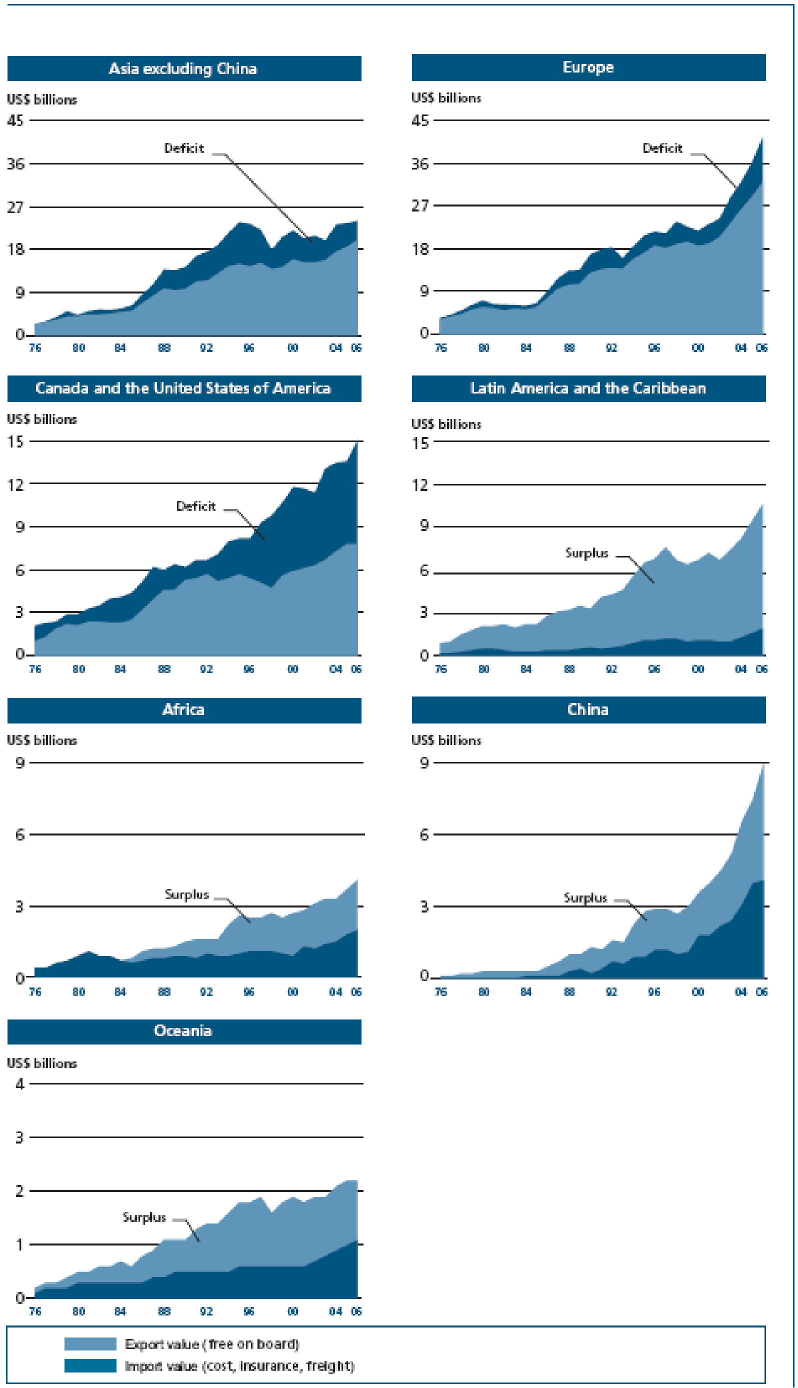
79 FAO Committee on Fisheries, Sub-Committee on Aquaculture, Fourth Session: Opportunities for Addressing the Challenges in Meeting the Rising Global Demand for Food Fish from Aquaculture. Puerto Varas, Chile, 6 - 10 October 2008

80 FAO Food Outlook June 2008 http://www.fao.org/docrep/010/ai466e/ai466e10.htm (accessed 7/10/2009)

81 FAO Committee on Fisheries, Sub-Committee on Aquaculture, Fourth Session: Opportunities for Addressing the Challenges in Meeting the Rising Global Demand for Food Fish from Aquaculture. Puerto Varas, Chile, 6 - 10 October 2008

Industrialised countries are increasingly importing aquatic products; in 2006, imports were worth around USD 78 billion. This corresponds to 80 percent of the international imports in value and 62 percent in quantity terms.[82] More than half of the imports (59 % in terms of quantity, 49 % in value terms) of the North are coming from the South.[83]

Imports and exports of fish and fishery products for different regions, indicating net deficit or surplus



Source: FAO (2009): The State of World Fisheries and Aquaculture 2008

[82] FAO Food Outlook June 2008 http://www.fao.org/docrep/010/ai466e/ai466e10.htm (accessed 7/10/2009)
[83] FAO (2009) The State of World Fisheries and Aquaculture 2008, Rome

Increasing value of exported products from the South

A part of the fisheries products exported from the South is fishmeal and fish oil: 35 percent in quantity, 5 percent in value. In the South-South trade, fishmeal and fish oil are dominating. But the share of developing countries in the food fish export had increased to 53 percent in 2006.[84]

China has become the largest fish exporter (export value was USD 9.7 billion in 2007). The most exported species are shrimp, mollusc, eel, tilapia, large yellow croaker, freshwater crayfish and river crab. But its imports are also growing, reaching USD 4.7 billion in 2007. About half of the increase in China's imports results from Chinese processors who import raw material from all over the world for re-processing and export, another 30 percent is for fishmeal.[85]

FAO notes an increasing globalization of the fisheries value chain, in which processing is being outsourced to Asia (e.g. China, Thailand and Viet Nam) and, to a lesser degree, Central and Eastern Europe (e.g. Poland and Baltic countries) and North Africa (Morocco). A few high value species, such as salmon, tuna and tilapia, are increasingly traded in the processed form.[86] Fresh whole fish can be more valuable than processed fish,[87] but the value increase of processed fish can also be considerable: A whole salmon is five times less expensive than salmon fillets and 10 times less than a smoked salmon.[88] It is discussed further below how this may affect smallholders.

The world's production of shrimp, captured and farmed, is approximately 6 million tonnes, about 60 percent of which is traded internationally. Annual exports of shrimp are currently worth more than US$14 billion, or 16 percent of all fisheries exports. This makes it the most important internationally-traded fisheries commodity. However, export growth rates for species such as catfish and tilapia currently exceed 50 percent per year. These species are entering new markets where, only a few years ago, they were practically unknown. According to FAO, this highlights the potential for further growth in the production, trade and consumption of species and products that respond to consumers' needs for moderately-priced whitefish fillets. Although the data do not yet distinguish farmed and captured products, most of these new products are probably farmed, and to a large part in the South.[89]

International trade rules and disputes affecting developing countries

No analysis of the role of developing countries in global trade would be complete without looking at trade rules and related disputes. In food industry investment analyses, they are a standard item.

Import tariffs are considered to be rather low, with exception of some processed products. However, importing countries are increasing their requirements with regard to quality and safety as well as animal health, environmental standards and social concerns.[90]

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[84] ibid.

[85] Kieran Kelleher, The World Bank (2008): International trade, small scale fisheries and food security. Global Conference on Small- Scale Fisheries Bangkok, October 2008 http://www.4ssf.org/docs/plenaryPresentations/08%20International%20fish%20trade%20and%20small%20scale%20fishers.pdf (accessed 7/10/2009)

[86] FAO Food Outlook June 2008 http://www.fao.org/docrep/010/ai466e/ai466e10.htm (accessed 7/10/2009)

[87] FAO (2007) State of World Aquaculture 2006, Rome

[88] Failler, P.: Future prospects for fish and fishery products. 4. Fish consumption in the European Union in 2015 and 2030. Part 1. European overview. *FAO Fisheries Circular.* No. 972/4, Part 1. Rome, FAO. 2007. 204p

[89] FAO (2009): The State of World Fisheries and Aquaculture 2008, Rome

[90] ibid.

International trade is increasingly influenced by international animal health regulations like those of the OIE and FAO's Codex Alimentarius. Similar to livestock, these regulations have become tools to control imports, sometimes welcomed by a domestic industry needing protection. Nontariff barriers, such as technical and sanitary standards, labeling, and traceability requirements to ensure food safety may be deployed to protect domestic producers. The cost of compliance with increasingly stringent food safety regulations also tends to exclude small producers and processors from export markets.[91]

A number of trade dispute cases, however, concern import tariffs, and impact smallholders.

Two US trade disputes

U.S. case on shrimp imports from Brazil, China, Ecuador, India, Thailand, Viet Nam

In 2003, the U.S. Southern Shrimp Alliance filed a petition to the U.S. authorities alleging that exporters from Brazil, China, Ecuador, India, Thailand, and Viet Nam had dumped shrimp on the U.S. market at below-cost prices, triggering a plunge in the value of U.S.-harvested shrimp from $1.25 billion in 2000 to $559 million in 2002. In 2003, shrimp imports from the six countries amounted to $2.67 billion. In 2005, the U.S. authorities imposed antidumping duties of up to 113 percent on imports of certain shrimp and prawns from the above six countries and, although the measures did not break the rising trend in shrimp imports, they negatively affected both volumes and share in imports of the concerned exporters.[(1)] Thailand and Ecuador took the case to the World Trade Organization to protest against the United States duties.[(2)]

U.S.-Viet Nam catfish trade dispute

Between January and November 2002, the United States imported 18,300 tonnes of Vietnamese catfish worth $55.1 million. The Catfish Farmers of America (CFA) complained that Viet Nam had captured 20 percent of the $590 million catfish market by selling at prices below the cost of production, and in mid-2003, U.S. authorities ruled that Vietnamese catfish fillets had been "dumped" or sold in the U.S. market at unfairly low prices, resulting in retroactive import duties of 37–64 percent. Catfish import duties were 5 percent before the rulings. Viet Nam maintained that its catfish were cheaper because of cheaper labour and feed costs. Subsequently, the U.S. Congress declared that only the native U.S. family, *Ictaluridae*, could be called catfish, effectively preventing the Vietnamese product from being marketed as catfish, and U.S. authorities initiated an antidumping case against Vietnamese catfish. Some half-million Vietnamese live off the catfish trade in the Mekong delta and the catfish dispute threatened the livelihoods of thousands of farmers until alternative markets were found.[(3)]

Sources: [(1)] USINFO 2004; WTO 2006; FAO 2006, cited after The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington; [(2)] Gillett, R. (2008) Global study of shrimp fisheries. FAO Fisheries Technical Paper. No. 475. Rome, FAO. 2008. [(3)] Lam 2003, cited after The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington

The trade in fish *between* developing countries represents only 25 percent of the value of their fishery exports. This trade should, according to FAO, increase in the future, partly as a result of the emergence of more liberal and effectively implemented regional trade agreements, and partly driven by the demographic, social and economic trends that are transforming food markets in developing countries. However, such trade is hampered by the

[91] The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington

fact that the majority of developing countries apply, in general terms, much higher import tariffs for all imported products than do developed countries.[92]

[92] FAO (2009): The State of World Fisheries and Aquaculture 2008, Rome

4 Industrialised aquaculture

Industrialisation of aquaculture probably started with salmon and trout farming in Northern countries and continued with another high value group of species, shrimp, both in industrialised countries and, for export, in Taiwan as well as in developing countries. Among other species grown in or being evaluated for industrial aquaculture, tilapia and catfish are playing increasingly important roles. Since the late 1980's, tilapia was promoted as an easy to grow and not high value species for farmers in developing countries; it is now grown for export and for local markets in many developing and industrialised countries. The catfish showed in statistics as the most popular fish in the USA, and more recently the pangasius catfish aquaculture for export boomed in Viet Nam. The following chapter describes industrialised aquaculture of the four groups of species, salmonids, shrimp, tilapia and catfish.

The livestock revolution model

Many of the mainstream analyses of the aquaculture growth in recent year focus on the industrialised sector. The development of an industrialised aquaculture has been supported and reported since many years and has been compared to the livestock "revolution". Similarly to the livestock revolution, high investments are needed to develop and put the technology in place. Public subsidies and fiscal incentives such as tax breaks play significant roles, so far predominantly in industrialised countries. In the South, lack or implementation flaws of labour laws and environmental regulation effectively subsidizes the development of aquaculture. The enabling conditions to allow the industrialised production to grow are often such that a level playing field with traditional production no longer exists. While in livestock, this is clearly the case,[93] in industrialised aquaculture, some enabling conditions have been set in many cases;[94] more decisions are to be expected with the policies of many governments and mainstream development organisations to industrialise aquaculture.

The term "industry" needs some clarification. Industrial fisheries or fishing used to apply to fishmeal and reduction fisheries – i.e. fisheries for industrial use, including feed for aquaculture. From the macroeconomic perspective, industry means the whole aquaculture (or even fisheries) sector, including a large variety of production systems, for local markets, own consumption, and for export.
"Industrialized" is the part where largely standardized products are produced with high external inputs (formulated feed provided by feed companies; veterinary products provided by the pharmaceutical industry; seed from hatcheries respectively from genetics companies). Production is not for the local, but for the national or international market, usually through a trading or processing company. Two capital intensive technologies are increasingly used: Offshore cage farms and inland closed circuit farms. Smallholders are not excluded from industrialised aquaculture, but often integrated as contractors. However, small-scale fishers, small-holders and their families may be displaced from their customary activities and living areas by industrial aquaculture, and incorporated into it as low cost labour.

Investment financing for aquaculture

Capital-intensive aquaculture is expanding. According to FAO, large potential is seen in off-shore aquaculture, and in the USA, the government has already prepared a legal and

[93] Susanne Gura (2008): Industrial livestock production and its impact on smallholders in developing countries. Consultancy report to the League for Pastoral Peoples and Endogenous Livestock Development (www.pastoralpeoples.org), Germany (accessed 7/10/2009)
[94] FAO (2009): The State of World Fisheries and Aquaculture 2008, Rome

regulatory basis for offshore aquaculture in the country's Exclusive Economic Zone.[95] There are reports of significant capital inflows into Latin America, particularly Brazil and Chile, for the culture of salmon and other species. Sizeable flows of foreign investments are also reported in sub-Saharan African countries including the Gambia, Namibia, Nigeria, Senegal and Uganda for the culture of species such as shrimp, catfish and tilapia.[96] Private capital plays a more important role, but public funding is also considerable. Between 1988 and 1995, official aid for aquaculture development amounted to USD 995 million, of which development banks financed 69 percent.[97] Even public funds from developing countries are provided to companies from industrialised countries, e.g. a hatchery in Malaysia (to an Australian company),[98] and salmon farms in Chile (to Norwegian, Icelandic, Japanese and EU multinational salmon companies). The government of Panama paid a USD 150,000 grant to a US/Panamaian company for an off shore farm to produce cobia (*Rachycentron canadum*) for the US market.[99]

Feed industry for aquaculture

It is often argued that an increased use of commercial fish feeds will reduce pollution because good quality commercial feeds are better digested and absorbed by the fish and cause less pollution. However, not only feed conversion ratios have to be looked into, but also the ecological footprint of the feed used (see box).

Commercial feeds are used in industrial aquaculture, and since they are entering the markets in an increasing number of developing countries, many smallholders also substitute part of the local feed by compound feed. Even herbivores are fed with industrial feeds that contain animal proteins – they will grow faster.

A large part of aquafeed is fish meal and fish oil, made from small pelagic fish like anchoveta in Peru. The conversion of such low cost, high food value fish incurs a significant opportunity cost for poor communities, where such fish could provide an important food source. The capture of such species may also impact directly on small-scale fisheries where industrial trawlers and purse seiners compete for space and resources with artisanal fishers, may deplete resources and damage the aquatic ecosystem, and may illegally enter artisanal fishing areas.

In Venezuela, until its recent demise, the sardinelle fishery used to provide for mass produced low cost canned sardines for the local population. In Peru, lack of environmental regulations, poor control, and lack of investment for infrastructure development makes fishmeal an attractive option over use of anchoveta and other pelagics for human food.

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[95] The U.S. exclusive economic zone (EEZ) extends 200 nautical miles offshore, encompassing diverse ecosystems and vast natural resources, such as fisheries and energy and other mineral resources. The U.S. EEZ is the largest in the world, spanning over an area larger than the combined land area of all fifty states. http://aquaculture.noaa.gov/pdf/20_eezmap.pdf (accessed 7/10/2009)

[96] FAO (2007) State of World Fisheries and Aquaculture 2006, Rome

[97] The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture

[98] Cell Aquaculture Australia (2008): "Land based Premium Aquaculture Production Specialist" www.austrade.gov.au/ArticleDocuments/1418/MAHA-Cel-Aqua-Aug08.pdf (accessed 7/10/2009)

[99] http://www.fishupdate.com/news/fullstory.php/aid/12160/Pristine_Oceans_S.A._receives_Panamanian_Government_Support_for_Open_Oceans_COBIA__Rachycentron_canadum__Aquaculture_Project_near_Portobello,_Col_F3n,_Republic_of_Panam_E1.html (accessed 7/10/2009)

Feed conversion in fish is better than in meat…

To produce a kilo of live fish, the feed industry claims to need only 2 kg of feed,(1) while poultry requires 3, and cattle 8-10 times the live weight.(2) Or, as the WorldFish international research center puts it, 100 kilograms of feed will produce as much as 75 kilograms of catfish meat but only 50 kilograms of chicken meat or 13 kilograms of beef. In fish the yield in relation to weight is high; this is in contrast to farm animals where the yield of edible meat is sharply reduced by bones, hooves, coat, or feathers.(3)

But the comparison between fish and livestock feed conversion is made at high the levels of pollution implied by compound or concentrate feed. An intensification of aquaculture using increased amounts of industrial feed will increase the ecological footprint of aquaculture.

… but a growth of industrial aquaculture may heat the climate

Industrial aquaculture production may contribute to global warming,

- where grain in the feed is derived from intensive land use (releasing CO_2 by clearing rainforests or grassland, e.g. soy from Brazil), chemical pesticides and fertilizer (produced with high petrol and energy input), and water (consumption and pollution are high in chemical agriculture).
- where feed includes internationally traded compounds, increasing emissions from transport
- where feed includes fish meal and fish oil, disturbing the oceans' food web,
- where high value fish is grown for export markets, with more farmers replacing home made feed with compound feed

(1) 1.2 kg of feed for 1 kg salmon, see Marine Harvest Annual Report 2007
(2) http://www.biomar.com/investor_relations_pdf_2008/BioMar_Annual_Report_2007.pdf
(3) Norwegian breeding strategies. Norwegian Genetic Resource Centre – a part of the Norwegian Forest and Landscape Institute. www.genressurser.no (accessed 7/10/2009)

The low economic value reflects neither the food value of the fish for human consumption nor the ecological value in the food web. The food of many fish and other marine predators (birds and mammals) may be depleted. Likewise the by catch of fish targeted by the artisanal sector and the degradation of the food web may impact negatively on artisanal fishing and food fish production. According to the World Bank, "high-value resources are slowly degraded, while the global fish supply from marine capture fisheries increasingly relies on lower value species."[100]

In the South East Pacific in particular, catches of small pelagic fish for fishmeal and fish oil fluctuate according to La Niña and El Niño, and related upwelling phenomena. The expansion of the industrialized aquaculture sector is encountering a bottleneck in feed supplies, whilst fish oil prices soared to an all-time record in 2008. 85 percent of fish oil is used by aquaculture, and salmonids are responsible for more than 55 percent of the sector's share.[101] While the fishmeal industry is exploring krill from the southern oceans as the next major feed resource,[102] aquaculture is increasingly competing for cereals and oilseeds. The scarcity of cereals and oilseeds, actually a reflection of scarcity of agricultural land, is used by proponents of genetically modified seed to promote GMO grains.

[100] World Bank (2008): Sunken Billions: The Economic Justification for Fisheries Reform, Washington
[101] FAO (2009): The State of World Fisheries and Aquaculture 2008, Rome
[102] The Antarctic and Southern Ocean Coalition (ASOC) October 2006: Ecosystem Management of Antarctic Krill in the South Atlantic. Uncertainties and Priorities

The largest Aquafeed companies

Skretting/ Nutreco Holding N.V. (Norway/The Netherlands)
Nutreco's subsidiary Skretting, is the world fish feed market leader with 40% market share, The Norway based subsidiary Skretting increased its sales from € 3 billion in 2005 to 4 billion in 2007. In 2008, a two-year salmon feed supply contract was concluded with Marine Harvest, the largest producer of farmed salmon in the world. 70% of the total requirements of Marine Harvest, a leading multinational seafood company, is supplied by Skretting. The first half of 2008 saw its revenue increase by 38% to EUR 2.3 billion.
The Nutreco Holding N.V., based in the Netherlands, is a globally operating animal nutrition and fish feed company, with some 9,000 employees located in around 100 production plants and eight research centres in 24 countries. Nutreco is the market leader in compound feed in Benelux, Spain and Canada, and the world's second in premix and specialist feed. Nutreco is listed in the Amsterdam Stock Exchange. In the global animal nutrition and fish feed industry, Nutreco claims the fifth position in terms of volume, and the third in terms of revenue.(1)

EWOS/Cermaq ASA (Sweden/Norway)
EWOS holds approximately 33 percent global market share. In 2007, the company sold a total of 847 400 tonnes of feed for salmon and trout (a 9 percent volume increase), and it increased its operating result by almost 50 percent to 41 million €. The business increases in spite of volatile prices are due, among others, to "forward positions" and various other mechanisms in feed contracts.(2)
The Norwegian mother corporation Cermaq ASA is active in fish feed (EWOS) as well as in salmon farming with farming operations in all major salmon growing areas - Norway, Chile, Canada and Scotland. Cermaq ASA started as a state grain trading company, and converted into a fish feed and farming corporation listed in the Oslo Stock Exchange.(3)

BioMar Holding A/S (Denmark)
The BioMar Holding A/S, based in Denmark, is the third largest supplier of fish feed mainly for salmon and trout in Norway, the UK and Chile, and for fresh-water trout, sea-bass and sea-bream in Europe. BioMar started off as a Danish company established in 1962 and is now listed on the Nordic Stock Exchange. With some 750 employees it produces 700,000 tonnes in several European countries and Chile, and holds a market share of 17 %. The company increased its sales from Euro 2,6 billion in 2005 to 3,6 billion in 2007.(4) In 2008, BioMar took over Provimi Aqua, the fish branch of animal feed provider Provimi, with factories in Chile, Denmark and Spain. Provimi Aqua is the world's fourth largest supplier of fish feed, including special formulations for eel, cod, and larval and fry feed, functional feeds, health products and medicated feeds.

(1) http://www.openingacademischjaar.wur.nl/UK/Speeches/Speech+Wout+Dekker (accessed 7/10/2009)
(2) http://www.cermaq.com/cermaq/cermaqen.nsf/0/3054452F86294C13C1256AAF004776AC (accessed 7/10/2009)
(3) ibid
(4) http://www.biomar.com/investor_relations_pdf_2008/BioMar_Annual_Report_2007.pdf (accessed 7/10/2009)

Large aquaculture feed companies are thriving and concentrating: major feed companies include Skretting/Nutreco Holding N.V; EWOS/Cermaq, and BioMar Holding A/S. Their shares of the global aquaculture feed market in 2006 were 40%, 34% and 18% respectively; other companies held 8% compared to 22% in 1998. Other large feed companies are developing their aquafeed production. These include CP Feed Mills, a subsidiary of Asia's largest meat processor Charoen Pokphand, and Cargill Inc., the world's largest grain trader and processor, and a major supplier of livestock feeds, who recently set up an aquaculture research facility in the USA.[103]

The lobbying and market power of the feed companies is considerable. For example, the CEO of feed market leader Nutreco Holding N.V., Wout Dekker, holds a leading position in formulating the European Union's aquaculture research and development vision.[104] Jointly with Kofi Annan, he opened the academic year of one of Europe's leading agricultural universities, Wageningen.[105]

Pharmaceutical industry for aquaculture: Disease growth
The industrial aquaculture sector is a big user of veterinary pharmaceuticals. Hormones, pesticides, antibiotics, vaccines, and antifouling paints are in common use. Antibiotic resistant bacteria were found on all aquaculture products included in recent studies from Chile and from the Netherlands. The latter concluded that any presence of antibiotic resistant bacteria on food products is a threat to public health and thus requires governmental intervention.[106]

There are a few successes to report where pharmaceuticals, e.g. antibiotics have been phased out and replaced by vaccines, like the often cited case of Atlantic salmon. Here this was achieved not only with use of vaccines but also thanks to good site selection, site rotation (one generation per site); improved production management; strict veterinary control of all farms; strict rules for movement of live fish; and use of approved medicines.[107] Industrialized aquaculture is known as an extremely risky business due to unmanageable pests and diseases: the pharmaceutical industry may therefore become one of aquaculture's fiercest supporters.

Smallholders are the "beneficiaries" but bear large risks
In densely populated Asia, where large land areas are not easily available, export oriented industrial aquaculture is often established through contract farming with smallholders. Traders and processing companies make part of the value chain. Farmers can be integrated by contract in corporate sourcing of raw materials which may include supply of input or credit. While insurance are increasingly available in industrialized countries and especially for capital intensive ventures, this is not the case for smallholders in developing countries.[108] OXFAM reported that in Thailand, 80 percent of shrimp farmers are indebted.[109] Nevertheless, the World Bank encouraged contract farming of shrimp as examples of successful pro-poor business models, and pointed out a shrimp-farming project in Indonesia where the farm concession covers an area of more than 20,000 hectares. More than 3,100 of the 3,750 ponds are owned and operated by smallholders under a form of contract farming. There are also examples of contract farming in Ecuador.[110]

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[103] http://www.cargillanimalnutrition.com (accessed 7/10/2009)
[104] European Aquaculture Technology and Innovation Platform (EATIP) Progress and Achievements Gustavo Larrazábal A. Ghent, February 3rd, 2009 http://www.eatip.eu/index.php?option=com_docman&task=doc_download&gid=302 (accessed 7/10/2009)
[105] http://www.openingacademischjaar.wur.nl/UK/Speeches/Speech+Wout+Dekker (accessed 7/10/2009)
[106] Ingrid Kleine Staarman (2008): Antibiotic resistance in aquaculture: a case study on the regulation of technology. Utrecht University http://www.uu.nl/uupublish/content/Kleine_Staarman_Ingrid_stageverslag.pdf (accessed 7/10/2009)
[107] Gregussen 2005 cited after The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture
[108] van Anrooy, R.; Secretan, P.A.D.; Lou, Y.; Roberts, R.; Upare, M. Review of the current state of world aquaculture insurance. FAO Fisheries Technical Paper. No. 493. Rome, FAO. 2006. 92p.
[109] Leo van Mulekom, Oxfam Novib (2007): NGO perspectives on aquaculture, aquaculture certification, and the responsibility of commodity buyers. Input to FAO Expert Workshop on Guidelines for Aquaculture Certification. London, 28-29 February 2007
[110] "Certificando la Destrucción" - http://www.ccondem.org.ec/cms.php?c=369 (accessed 7/10/2009)

Contract farming a pivotal instrument?

In such contract farming schemes companies do not actually own farm ponds, but provide credit to small scale farmers for the purchase, development and operation of ponds, while often dictating the sourcing of inputs as well as the product prices. In this way, large companies can access public land (“for development”), use government credit schemes (“to assist small-scale farmers”), and control the production process (via conditions posed in credit-schemes) without having to take the investment risks and establishing ponds themselves.[111]

The World Bank promotes contract farming in aquaculture as it did before in plant crops and livestock. “A mature industry has the critical mass to benefit from economies of scale, to spread risk to the service industries and specialist providers” reasons the World Bank.[112] However, very often the risk is passed on to the smallholders, as shown from examples in the livestock sector. [113]

According to the WorldFish Centre, in Thailand, Indonesia, and the Philippines, contract farming of prawns and tilapia awarded to small-scale farmers by big firms has enabled the disadvantaged poor to reap some of the benefits of large scale operators. The recent aquaculture and export boom has prompted international funding agencies to extend more loans to developing countries than in the past. The ADB, World Bank, and various bilateral institutions (such as the United States Agency for International Development (USAID), UK Department for International Development (DFID), and Danish International Development Agency (Danida) have been active in funding resource management, aquaculture development, and post-harvest and processing projects.[114]

Many Asian governments (including Malaysia, Bangladesh, Indonesia, and Thailand) assist smallholders through the provision of loans, often subsidized, channelled to associations, special agencies (agricultural banks, Indonesian Peoples’ Bank) and loan schemes (Special Agricultural Credit Scheme and Fund for Food Scheme in Malaysia).[115]

The projects tend to become larger and more intensive, but are almost always targeted at smallholders, or, more generally, “people”: With its “Aquaculture for the Malaysian People Concept”, Cell Aqua Malaysia, the Malaysian subsidiary of Cell Aquaculture Ltd Australia plans to develop one of the largest commercial hatcheries in South East Asia, supplying fingerlings to smallholders for a production capacity of at least 1,200 tonnes per year. In a joint venture with Terengganu Agrotech Development Corp it has established a facility (including closed circuit technology) next to the Malaysian Federal Marine Research Centre.[116] The project is carried out by an Australian company, and expected to be financed by the Malaysian government.

[111] Leo van Mulekom, Anna Axelsson, Ephraim Patrick Batungbacal, Dave Baxter, Radja Siregar, Isabel de la Torred, SEAFish for Justice Trade and export orientation of fisheries in Southeast Asia: Under-priced export at the expense of domestic food security and local economies. Ocean & Coastal Management 49 (2006) 546–561

[112] The World Bank (2006): Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture, Washington

[113] Susanne Gura (2008): Livestock: Contracted in Global Value Chains. Exploitation of producers instead of “win-win” World Economy and Development 3/May-Jun 2008

[114] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p.

[115] ibid.

[116] Cell Aquaculture Australia (2008): “Land based Premium Aquaculture Production Specialist” www.austrade.gov.au/ArticleDocuments/1418/MAHA-Cel-Aqua-Aug08.pdf (accessed 7/10/2009)

Contract farming is being promoted in aquaculture in spite of major doubts whether it is a win-win approach, or rather a tool to exploit smallholders.[117] More data are needed (agricultural production contracts are not even registered in most countries), as well as policies that strengthen smallholders vis-à-vis strong corporate contractors.

Environmental problems

Better feed conversion rates (less feed per output) does not help the environment so long as the feed is based on unsustainable feed resources like fishmeal, fish oil, and grains produced with high chemical input, and where industrial aquaculture is the cause of increasing levels of environmental pollution. Environmental problems include:

- Monoculture of species fed to grow as fast as possible are associated with high biological loads in the waste water, from faeces, poorly digested feed, and unconsumed feed
- There are massive escapes from marine farms, with escapees (often exotic species) invading the surrounding environment, competing with and predating on other (often commercial) fish species, affecting artisanal and other fishing operations, and spreading disease.
- Approximately 17 percent of the world's finfish production is based on species alien to their environment. Especially, tilapia have been spread from Africa to aquaculture farms in more than 50 countries. According to FAO, aquatic ecosystems may be affected by the introduced species through predation, competition, mixing of exotic genes, habitat modification and the introduction of pathogens. Human communities may also be impacted through change in fishing patterns due to a newly-established fishery or through changes in land use and resource access when high valued species are introduced into an area.[118]
- In many parts of the world, large areas of mangroves have been destroyed in order to establish shrimp aquaculture,
- International seafood trade in fresh and frozen products, thanks to low air freight rates, have contributed to increasing air transport. Intercontinental airfreight may emit 8.5 kg CO2 per kg of fish shipped, about 3.5 times the levels from sea freight, and more than 90 times greater than emissions from the transport of fish consumed within 400 km of its source.[119] Thus, export oriented aquaculture entails a considerable, and increasingly large carbon footprint.

FAO stated in its 2006 State of Fisheries and Aquaculture report that some of these effects can indeed jeopardize the options for future generations to benefit from the full range of goods and services provided by ecosystems.[120]

Certification: A way forward or way out ?

In recent years, eco-certification has been applied to fishery products as a way to promote (environmentally and socially) sustainable practices. In the case of aquaculture products, this has involved applying the concept of organic farming or "sustainable agriculture" to fish production.

However, many questions have been raised about the nature of such ecolabels, and about their various claims. In particular the application of "organic" labels to carnivorous species in

[117] Susanne Gura (2008): Livestock: Contracted in global value chains. Exploitation of producers instead of "win-win" World Economy and Development 3/May-Jun 2008
[118] http://www.fao.org/fishery/topic/13532 (accessed 7/10/2009)
[119] Climate Change for Fisheries And Aquaculture. Technical Background Document from the Expert Consultation 7 to 9 April 2008, FAO, Rome
[120] FAO (2007) State of World Fisheries and Aquaculture 2006, p.77

aquaculture has been questioned. So too the certification of tropical shrimp from Asia and Latin America as environmentally and socially sustainable has been sharply criticised.[121] [122] [123]

Ecolabelling may well be just a short-term solution to maintain the status quo of industrial fisheries and international trade in high-value species, assessed the civil society participants of the first FAO conference dedicated to small-scale fisheries on “Securing Sustainability in Small-scale Fisheries” (4SSF), held in Bangkok in October 2008. They offered the alternative of Informal area-specific labels.[124]

Industrial farming of salmon

Industrialized aquaculture is most advanced in salmonids (salmon and trout species), but they constitute only 7 percent of global aquatic animal production. The share of salmon (including trout) in world trade has increased strongly in recent decades and now stands at 11 percent.[125] Farming salmonids took off during the 1970s, and the growth of selective breeding programmes in Norway was one of the main driving forces. In the last decade the salmon farming industry has been through a period of consolidation; the number of companies producing 80 percent of farmed salmon was reduced by half. [126] Farmed salmon is mainly produced in Norway, UK,, Canada and Chile, but marketed around the world. Sales are increasing in Japan, Brazil, Ukraine and Russia.

Farmed salmon represented less than 10 percent of the global supply 20 years ago, whereas it now accounts for over 60 percent of the salmon market.[127] This is due both to the demise of wild stocks and to massive increases and expansion in production. The detrimental effect of the farming on the wild population may be, however, larger than the benefit. Small-scale salmon fishers, particularly First Nations in Northern America, have long complained that waste from the farms is dangerous to wild stock, and that farmed salmon spread disease and contribute to higher concentrations of sea lice that cripple young wild salmon. After vainly communicating their concerns to the Canadian federal and British Columbian provincial governments, a First Nation lodged a class action suit against the British Columbian government. The legal action will be the first class-action lawsuit in Canada launched to protect aboriginal treaty rights.[128]

Farmed salmon production is largely based on a few breeding strains, developed for maximum return and fast growth. Their wild relatives, in contrast, are the products of thousands of years of evolution, adapted to challenging environmental pressures. Therefore the morphology of farmed salmon, altered for both producer and consumer, is at a disadvantage in the wild. Hampered by reduced body streamlining, shorter fins, higher fat content, reduced swimming performance and differently shaped hearts, the farmed salmon are less prone to survival in open waters.

[121] Verónica Yépes (2008): The Privatization of Mangroves. In: Samudra Report 51 http://icsf.net/icsf2006/uploads/publications/samudra/pdf/english/issue_51/art13.pdf (accessed 7/10/2009)
[122] Brian O'Riordan (2007): Cerifying the Uncertifyable. In Samudra Report 48. http://icsf.net/icsf2006/uploads/publications/samudra/pdf/english/issue_48/art07.pdf (accessed 7/10/2009)
[123] Lampung Declaration Against Industrial Shrimp Aquaculture. Outcome of meeting in Lampung, Indonesia, to address the continuing expansion and associated impacts of industrial shrimp aquaculture. WAHLI, Lampung, Indonesia, 6 September 2007
[124] Paul Molyneaux (2008) Certifying the Certifiers In: Samudra Report 51
[125] FAO (2009) The State of World Fisheries and Aquaculture 2008, Rome
[126] Marine Harvest Industry Handbook 2008
[127] http://www.biomar.com/investor_relations_pdf_2008/BioMar_Annual_Report_2007.pdf (accessed 7/10/2009)
[128] Dirk Meissner, Press News Limited http://www.seafoodnews.com/newsemail.asp?key=499503 (accessed 7/10/2009)

Escaped salmon often interbreed with wild fish stocks. This has a detrimental effect on the wild salmon gene pool, consequently lowering their survival rate. In a ten year study it was estimated that 70 percent of these hybrid fish died in the first few weeks of life, whilst those that did survive could then go on to contaminate the gene pool once again. In spite of this, there is evidence that the farmed salmon actually have a competitive edge over their wild relatives at an early stage in their lives because of a more aggressive nature and faster growth pattern. Farmed salmon and hybrids can be expected to interact and compete directly with wild salmon for food, habitat and territories, adding extra pressure to their depleting stocks. There are also threats from the transmission of diseases and parasites.[129]

There are however, also increasing problems, e.g. the breakdown of the Chilean salmon industry first due to salmon lice, later due to a virus causing Infectious Salmon Anemia. Chile, within a few years of establishing a salmon industry, was producing around one fifth of global output. Higher water temperatures allowed a more intense production without fallow periods. The leading salmon producer, Marine Harvest, recently called to the whole industry not to drive intensification too far.[130] [131]

The Chilean salmon industry is asking for massive subsidization of their sector, and low-interest State guaranteed loans to ride through the crisis, which in many ways is of their own making. Many workers have been laid off, and are now being hired back through government employment creation schemes.[132] [133] [134]

The ICSF argues that industrial salmon aquaculture geared mainly towards the export market may have contributed to foreign exchange earnings and high profits to investors, but that benefits to workers and local communities have been meagre.[135]

Industrial farming of shrimp
With a value of US$10 billion (or 16 percent of world fishery exports) shrimp is one of the most important internationally traded fishery products. World production of shrimp, both captured and farmed, is about 6 million tonnes. About 40 percent is from aquaculture, and this production is mostly for export. Between 1997 and 2004, shrimp aquaculture production grew by around 15 percent annually.[136] Major public grants and loans, e.g. from Asian Development Bank and the International Finance Corporation of the World Bank Group, fostered this growth.

In Asia, the major food processing and trading company Charoen Pokphand or CP Group is a main actor. CP Group now has three major shrimp aquaculture companies with businesses in China, India, Indonesia, Thailand and Viet Nam. CP Feed Mills is the largest shrimp feed company in the region, while the CP Aquaculture and CP Intertrade branches involve the CP Group in the full cycle of production from inputs to overseas marketing. CP

[129] Thorstad, E.B., Fleming, I.A., McGinnity, P., Soto, D., Wennevik, V. & Whoriskey, F. 2008. Incidence and impacts of escaped farmed Atlantic salmon *Salmo salar* in nature. INA Special Report 36. 110 pp. http://www.asf.ca/docs/uploads/impacts-escapes-2008.pdf (accessed 7/10/2009)
[130] Marine Harvest Annual Report 2007
[131] Alexei Barrionuevo, 2009. New York Times http://www.ecoceanos.cl/index.php?option=com_content&task=view&id=7816&Itemid=52
[132] Patagonia Times, January 26, 2009
[133] Consultan por responsabilidad de empresas noruegas en aparición de virus ISA en Chile - http://www.ecoceanos.cl/index.php?option=com_content&task=view&id=7804&Itemid=52 (accessed 7/10/2009)
[134] Ecoceanos News October 2008. No! Not with our Money! http://www.ecoceanos.cl/index.php?option=com_content&task=view&id=7254&Itemid=52 (accessed 7/10/2009)
[135] Statement of the International Collective in Support of Fishworkers to the Third Session of the Sub-Committee on Aquaculture, Committee on Fisheries (COFI), Food and Agriculture Organization of the United Nations (FAO), New Delhi, India, 4 - 8 September 2006
[136] 2006 FAO (2007) State of World Fisheries and Aquaculture 2006, Rome

controls approximately 18% of Thai shrimp exports, and 60% of the Thai shrimp feed market. CP is also 31% co-owner of the single largest shrimp aquaculture company in Indonesia, the PT Central Pertiwi Bratasena. PT CPB is one of three companies that, together, control 90% of the production and export of shrimps in Indonesia.[137]

Shrimp markets are subject to typical international commodity trade fluctuations and policies. During the US economic depression after the World Trade Center attack in 2001, exports to the US decreased. After they resumed, the USA in 2004 raised import tariffs on shrimps from Brazil, China, Ecuador, India, Thailand and Viet Nam, and in consequence, these countries looked for other markets. In Europe, shrimp imports increased in 2005, also supported by a strong euro. The relaxing of EU restrictions on imports of Chinese farmed shrimp was reflected in an increase of supply from China, notably in Spain. International trade in shrimps is decreasing since the beginning of the current financial crisis.[138]

In shrimp farming, the misapplication of chemicals and the introduction of alien species, with escapes of cultured shrimp into the wild, are all matters of concern. Most of the shrimp seed today no longer relies on wild-caught shrimp juveniles post larvae, but comes from hatcheries. Wild catch is still common in Bangladesh and Ecuador, where collection is not prohibited.[139]

The export oriented large-scale development of shrimp farming has resulted in the degradation of wetlands and mangroves, and has also caused water pollution and salinization of land and freshwater aquifers.[140] OXFAM estimates the value of losses occurring to the ASEAN member countries to be USD 11-14 billion.[141]

In Ecuador, around 70 percent of the original mangrove area have been cleared. A decree of October 2008, completely ignoring existing protection legislation, provides concessions to the shrimp industry by regularizing their illegal activities in areas categorized as national assets for public use and thus deprives local communities of their sources of life and livelihoods.[142]

The environmental problems have triggered an international discussion how to render shrimp farming more sustainable.[143] A number of certification schemes have been developed. Most of them, however, hardly address social standards and are therefore rejected by many local communities.[144] OXFAM estimates, that several hundred of thousands have lost their land with the establishment of shrimp farms, and many have ended up in the highly risky contract farming. In Viet Nam, 80 percent of shrimp farmers are indebted. In Indonesia, with the increase of industrial shrimp farming, domestic shrimp consumption was reduced by half.[145]

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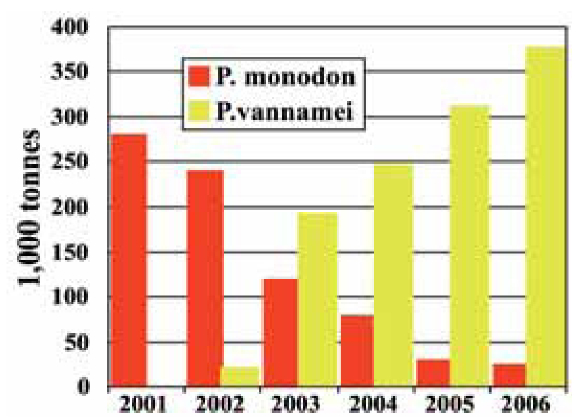
[137] Leo van Mulekom, Anna Axelsson, Ephraim Patrick Batungbacal, Dave Baxter, Radja Siregar, Isabel de la Torred, SEAFish for Justice Trade and export orientation of fisheries in Southeast Asia: Under-priced export at the expense of domestic food security and local economies. Ocean & Coastal Management 49 (2006) 546–561
[138] FAO Food Outlook, various editions
[139] Gillett, R. (2008) Global study of shrimp fisheries. FAO Fisheries Technical Paper. No. 475. Rome
[140] FAO (2007) State of World Fisheries and Aquaculture 2006, Rome
[141] Leo van Mulekom, Oxfam Novib (2007): NGO perspectives on aquaculture, aquaculture certification, and the responsibility of commodity buyers. Input to FAO Expert Workshop on Guidelines for Aquaculture Certification. London, 28-29 February 2007
[142] Verónica Yépes (2008): The Privatization of Mangroves. In: Samudra Report 51 http://icsf.net/icsf2006/uploads/publications/samudra/pdf/english/issue_51/art13.pdf (accessed 7/10/2009)
[143] FAO/NACA/UNEP/WB/WWF (2006): International principles for responsible shrimp farming. Bangkok, NACA.
[144] Lampung Declaration Against Industrial Shrimp Aquaculture. Outcome of meeting in Lampung, Indonesia, to address the continuing expansion and associated impacts of industrial shrimp aquaculture. WAHLI, Lampung, Indonesia, 6 September 2007
[145] Leo van Mulekom, Oxfam Novib (2007): NGO perspectives on aquaculture, aquaculture certification, and the responsibility of commodity buyers. Input to FAO Expert Workshop on Guidelines for Aquaculture Certification. London, 28-29 February 2007

In India, about 95% of the farmed and landed shrimp are exported, but domestic markets for shrimp and other aquaculture species are growing with the advent of retail chains. Much of the production is by smallholders who operate with credit in a “buy back system”, i.e. under contract with the buyer.[146] The Indian subsidiary of Oceanaa Group, a multinational shrimp processor, is offering contracts to shrimp outgrowers, supplying seed and feed under the buyback system.[147]

In Thailand, an outbreak of White Spot virus in the early 1990s nearly wiped out the aquaculture industry and caused many producers to go out of business.[148] In Latin America, Taura Syndrome and White Spot viruses "both implicated in the catastrophic USD 280 million collapse of the Ecuadorian shrimp industry in 1999, reducing production to less than a quarter. White Spot virus, in particular, has caused over USD 1 billion of production losses in the Americas since the 1990s."[149] Shrimp farming represents the third largest economical activity of Ecuador, preceded only by the petroleum and banana industries.[150]

The diseased shrimp species in Thailand in the 1990s were Asian native species (predominantly Black tiger prawn *Penaeus monodon*). Overintensification, environmental degradation and other factors led to the emergence and establishment of many viral diseases in the Black tiger prawn. Due to the diseases, a new species was introduced from the USA, the Pacific White, or Whiteleg shrimp *Penaeus vannamei*. The use of specific pathogen free broodstock was seen as a means of combating these disease problems. However, many of the viral diseases that had affected the Black tiger prawn were also found to affect the Pacific White shrimp, and new viral diseases have also begun to appear. Despite this experience, there is lobbying towards introduction of yet another exotic species, *Penaeus stylirostris*, for which specific pathogen free broodstock have been developed. Again introductions seem to be poised to occur with out considering the long term effects on biodiversity, disease risk or other potential environmental impacts.[151]



Leo van Mulekom, Anna Axelsson, Ephraim Patrick Batungbacal, Dave Baxter, Radja Siregar, Isabel de la Torred, SEAFish for Justice Trade and export orientation of fisheries in Southeast Asia: Under-priced export at the expense of domestic food security and local economies. Ocean & Coastal Management 49 (2006) 546–561

[146] National Institute of Agricultural Extension Management (2008): Sustainable Brackishwater Aquaculture: Issues and Challenges. Rajendranagar, India

[147] The Hindu, 18 April 2008

[148] IUCN, WWF, Friends of the Earth (2007): Good practices from the natureandpoverty* programme, The Netherlands

[149] http://www.aquabounty.com/media/IMS2Ecuador.html (accessed 7/10/2009)

[150] http://www.kuleuven.be/research/researchdatabase/project/3E06/3E060792.htm (accessed 7/10/2009)

[151] Sena S. De Silva, C.V. Mohan and Michael J. Phillips: A different form of dumping: The need for a precautionary approach for yet another new species for shrimp farming in Asia Sustainable Aquaculture, October-December 2007

Thailand annual shrimp farming production by species[152]

By 2005, global farming of Pacific White shrimp was 1,6 million tonnes, more than double the amount of the local Asian Black tiger prawn.[153] But now, policies may be revised. Thailand, for example, forecasts lower harvests of Pacific White shrimps, reflecting a shift by farmers towards more profitable black tiger shrimp, as well as tilapia.[154] Thai shrimp farmers have asked the government for support to revive Black tiger shrimp farming, claiming that they produce a more sustainable income than Pacific white shrimp.[155] Also, farmers in India and Viet Nam were planning to return to the native shrimp species,[156] but the Government of India has cleared importation of Pacific White Shrimp from specific international hatcheries. The Philippines, who had earlier banned Pacific White shrimp, had lifted the ban in 2007 to allow in the exotic species.
The WorldFish Center recently pointed out that shrimp technologies which were the most profitable and cost-effective were extensive and semi-intensive.[157]

The Norwegian Research Council and the India Government's Department of Biotechnology are funding public research organizations NOFIMA, and India's Central Institute for Freshwater Aquaculture (CIFA) and Central Institute for Brackish Water Aquaculture (CIBA) to develop marker technology in order to develop White spot virus resistant tiger shrimp.[158]

The ICSF assesses industrialized shrimp aquaculture to have led to serious socioeconomic problems, including severe conflicts, and even violence against local communities, associated, in particular, with land alienation; diversion of farm land; disruption of access to fishing grounds; negative impact on biodiversity, including of mangroves; salinization and overexploitation of water, including groundwater; and pollution. In India, concerted action by civil society to highlight these problems resulted in a landmark judicial pronouncement, which then played a major role in state regulation of irresponsible shrimp aquaculture.[159]

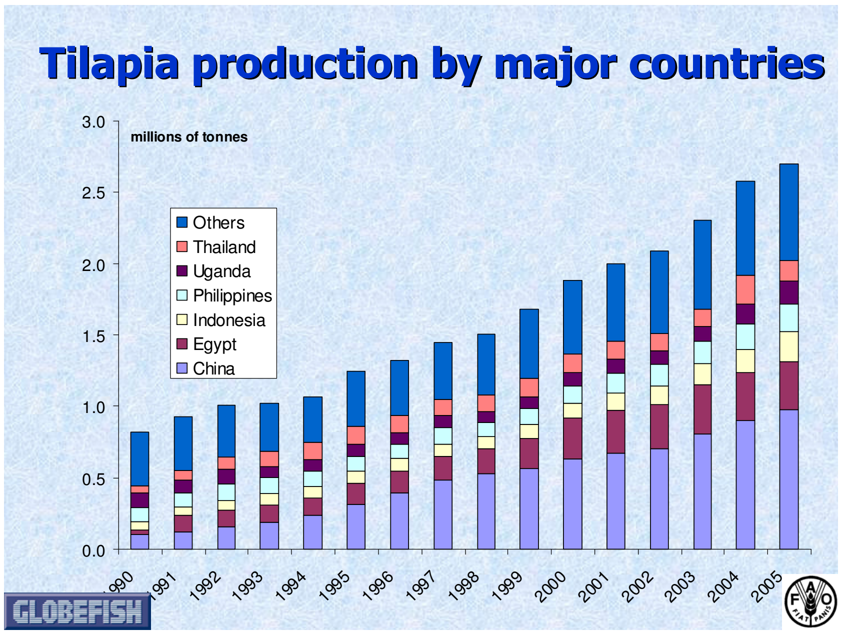
Industrial farming of tilapia

Tilapia farming has a history dating back over 2,000 years in the Middle East. The fish has since been transplanted to many regions outside its natural range (including North and South America, and Central, South and South East Asia). In the main stocks under cultivation today constitute hybrids of a variety of species.

In the context of developing, particularly Asian countries, an important selective breeding programme for tilapia was initiated during the 1990s in the Philippines by ICLARM (now called the WorldFish Center) Tilapia was the species chosen for this strategic research because of its importance in freshwater aquaculture and its short generation time of about 6 months, which would allow rapid results of breeding experiments and rapid dissemination of

[152] http://www.hihealthshrimp.com/pdf/AquaCultureMag_May07wyban.pdf (accessed 7/10/2009)
[153] Gillett, R. (2008) Global study of shrimp fisheries. FAO Fisheries Technical Paper. No. 475. Rome, FAO
[154] FAO Food Outlook November 2008
[155] SeafoodSource.com. Thai Shrimpers Seek Black Tiger Revival. June 25, 2008.
[156] TheFishSite News Desk September 29, 2008
[157] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p.
[158] Norway Boosts Disease Resistant Shrimp and Carp. The FishSite, December 15, 2008
[159] Statement of the International Collective in Support of Fishworkers to the Third Session of the Sub-Committee on Aquaculture, Committee on Fisheries (COFI), Food and Agriculture Organization of the United Nations (FAO), New Delhi, India, 4 - 8 September 2006

improved breeds. The improved strains were distributed mainly to public hatcheries in developing countries. Networks among countries at various levels accelerated the dissemination on strains and information on improved tilapia farming practices. Production increased from around 0,8 million tonnes in 1990 to 2,8 million tonnes in 2005. Main producing countries are China and Egypt, with strong increases in Latin America.[160]



Source: Helga Josupeit, World tilapia trade. INFOFISH Tilapia Conference, Kuala Lumpur, August 2007

Annual international trade with 200.000 tonnes is still relatively unimportant, but it is rapidly expanding: It doubled between 2003 and 2006, with Ecuador showing particularly sharp increases. China is the largest exporter, the USA are the largest importer. Europe's imports are growing. FAO (Globefish) notes that there are investments by foreign companies in tilapia farms, and processed products are increasingly traded internationally.[161] Examples for recent export oriented investments are US private investment in Honduras, EU private investment in Ghana, and World Bank in Nigeria. Specialized technology companies, e.g. Aquaculture Production Technology Ltd. from Israel, are establishing vast farms.[162] The World Wildlife Fund and the Global Aquaculture Alliance are about to finalize guidelines for their tilapia farm certification.[163]

Genetically Male Tilapia (not: Genetically *modified* tilapia) is the all-male offspring of sex-reversed grandparent. Normal genetic males (having XY chromosomes) are treated with female hormones and develop female gonads. When used as females for breeding, 25 percent of the offspring will be super male (having YY chromosomes). These supermales are the fathers of the fry and fingerlings sold to out-growers which are all male (having XY chromosomes).

In the export oriented tilapia production, where tilapia are usually bred in public or private large hatcheries, Methyltestosterone is used to induce sex reversal to producing 100%

[160] Helga Josupeit (2007) World tilapia trade. INFOFISH Tilapia Conference, Kuala Lumpur, August 2007
[161] ibid.
[162] http://www.aquaculture-israel.com/index.htm (accessed 7/10/2009)
[163] Globefish Tilapia Market Report - December 08

males, as male tilapia grows faster than female. For example, as in six commercial hatcheries in Indonesia.[164] But the male hormone is not easily decomposed, and there are concerns over the impact on the environment and to health,[165] including the health of female fish workers when they are affected by the male hormone.

In tilapia culture, Streptococcus bacteria occur in intensive, especially recirculating, production systems, and Vibrio bacteria have also been reported from marine and brackish water cultures. Medicated feeds are commercially available, and antibiotic resistance was reported in Brazil. Tilapia sometimes get heavy infestations of external parasites, which can affect growth rates. Contamination of fish with malachite green or methylene blue used to treat external parasites is reported.[166]

Industrial farming of catfish (Pangasius, Clarias and other species)

Between 2000 and 2005, global catfish production tripled. While earlier the USA and Thailand had been the main producers, they were overtaken by China and Viet Nam. Also, Indonesia increased its production. Since 2007, Viet Nam is the largest producer.
Catfish has been farmed in the Mekong Delta of Viet Nam for many years. Traditionally, the industry depended on wild-caught seed, mainly from Cambodian Mekong. Pangasius is an omnivorous fish that adapts well to different feeds and can survive even in water with a low oxygen level. Stagnation has been reported in the export sector, possibly due to the global recession.[167] Some export of catfish (mainly two species: tra *Pangasius hypophthalmus* and basa *Pangasius bocourti)* began in the mid-1980s primarily as fillet to Australia.[168] Shortly after the Cambodian government banned the tra catfish seed collection from the wild in 1994, artificial spawning was developed. Hundreds of hatcheries sprung up, supplying fingerlings to thousands of farmers.[169] The main export market became the USA. However, the US government has raised tariffs on imported Vietnamese catfish products. Vietnamese exporters were forced to look for other markets. In 2008, Viet Nam exported more than 550,000 tonnes of pangasius, for a value of around USD 1.5 billion. The EU is the main common market for pangasius from Viet Nam, with about one third of imports in both quantity and value terms. European countries import the raw material or semi-finished products with which to undertake their own value addition. Russia (20%) and Ukraine (13%) are the main single importing countries.[170] The quantity used for local consumption is estimated to be less than 1 percent and consists mostly of fish that die in transportation to processing plants.[171] However, Vietnamese catfish farmers are economically very vulnerable, as they operate not far above the break even point.[172]

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[164] Budhiman, A. 2007. Freshwater fish seed resources in Indonesia, pp. 329–341. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical paper. No. 501. Rome, FAO. 2007. 628p.

[165] Tayamen, M.M. 2007. Freshwater fish seed resources in the Philippines, pp. 395–424. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p.

[166] Kevin Fitzsimmons: Tilapia quality and safety in global markets. Honolulu, 23 Oct, 2007

[167] http://www.eurofish.dk/indexSub.php?id=3700 FISH INFO Network Market Report. Pangasius Market Report November 2008 (accessed 7/10/2009)

[168] Simon Wilkinson, NACA Better management practices for Vietnamese catfish, in: Aquaculture Asia Magazine, April-June 2008

[169] Hung, H.P, An, N.T.T., Trieu, N.V., Yen, D.T., Na-Nakorn, U. and Nguyen, T.T.T. (2008) Genetics and biodiversity : Some technical and management aspects of catfish hatcheries in Hong Ngu district, Dong Thap province, Vietnam. In: Aquaculture Asia Magazine Vol. XIII, No. 4 October-December 2008

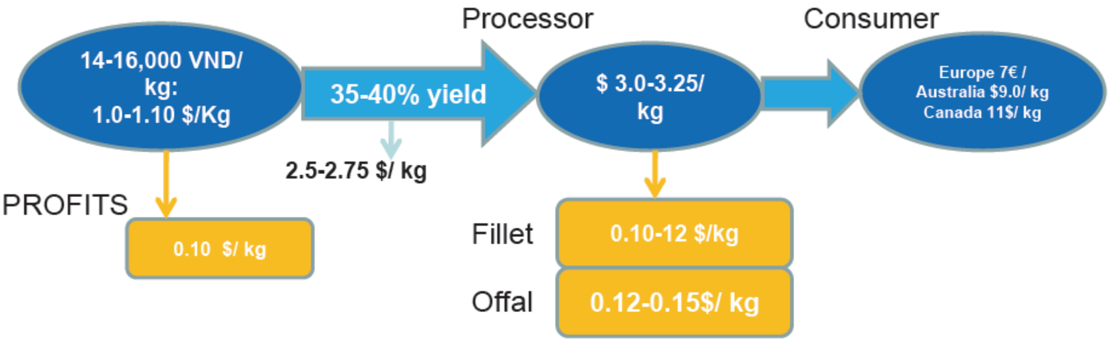
[170] Pangasius Market Report - February 2009FAO Globefish Pangasius Market Report - February 2009

[171] De Silva, S.S. Market chains of non-high value cultured aquatic commodities: case studies from Asia. FAO Fisheries and Aquaculture Circular. No. 1032. Rome, FAO. 2008. 46p.

[172] Phuong, N.T., Sinh, L.X., Thinh, N.Q., Chau, H.H., Anh, C.T. and Hau, N.M. (2007). Economics of aquaculture feeding practices: Viet Nam. In M.R. Hasan (ed.). Economics of aquaculture feeding practices in selected Asian countries. FAO Fisheries Technical Paper. No. 505. Rome, FAO. 2007. pp. 183–205.

Thailand and Malaysia were also reported to have started expanding their respective catfish farming to tap a bigger share of the global pangasius market. Equally trying to benefit from the pangasius export boom from Viet Nam to Europe, the feed company Vitarich Corp in the Philippines offers a line of products and services for investors in pangasius contract farming, including fingerlings and feeds, as well as buyers.[173]

The profit made by smallholder producers of pangasius farming in Viet Nam was calculated by Sena de Silva to be USD 0,10 per kg, around 1 percent of what consumers in industrialized countries were paying.[174]



Source: Sena S De Silva (2008): Aquaculture developments for the Asian region and associated issues that needs attention. APFIC Regional Consultative Forum, Manado, Indonesia, 6thto 9thAugust 2008

The rapid growth of the pangasius aquaculture industry has raised a number of environmental and social concerns. The WWF reported that eight key issues were identified during the first meeting of the Pangasius Aquaculture Dialogue:

1. Legal: Farms are sometimes constructed and/or operated outside the legal framework for addressing environmental, social and food safety issues of relevance to the area where the farming occurs
2. Land use and water use: As new farms are established, sensitive habitat can be destroyed and water often is diverted, which can affect other water users and the environment
3. Water pollution: Excess waste can pollute the water and negatively affect plant and animal habitat
4. Escapes: Pangasius that escape from aquaculture facilities may compete with wild fish and affect ecosystems, especially in areas where pangasius is not yet established
5. Feed management: Use of fishmeal, fish oil and trash-fish as pangasius feed is resulting in depletion of food sources that other fish rely on. Also, feeding trash-fish to pangasius can cause unsustainable harvesting and water pollution
6. Health management: Pangasius farms are prone to health problems that can impact farmed and wild stocks

[173] Philippine Daily Inquirer, 05/11/2008
[174] Sena S De Silva (2008): Aquaculture developments for the Asian region and associated issues that needs attention. APFIC Regional Consultative Forum, Manado, Indonesia, 6thto 9thAugust 2008

7. Antibiotics/chemicals: Inappropriate use of antibiotics and chemicals can have unintended consequences on the environment and human health, such as antibiotic resistance and unsafe products
8. Social responsibility/user conflicts: Large numbers of workers are employed on pangasius farms and in processing plants, placing labour practices and worker rights under public scrutiny. Also, conflicts can arise among users of the shared resources.[175]

For African aquaculture, African catfish (*Clarias gariepinus*) is among the species considered to have potential. It has several biological traits that make it a suitable species for aquaculture. Fish reach sexual maturity within the second year of their life, reach market size within the first season of growth and tolerate harsh environmental conditions. They are also suitable for polyculture, highly acceptable on the market and can survive for several hours even outside the water which minimizes their transportation requirements to the market. [176] The WorldFish Center is carrying out a genetic improvement project of African catfish that uses selective breeding technology. Polyculture of tilapia with African catfish is promoted and adopted by fish farmers in Egypt.[177]

A Dutch company, Fleuren and Nooijen Fishfarms Ltd, is producing hybrid *Clarias gariepinus* crossed with *Heterobranchus longifilis*. Fry or fingerling hybrids are sold as a final product for outgrowing; They cannot be used for reproduction. The advantage for outgrowers is a higher dressing yield. However, the hybrid exhibits cannibalism, and large variation in body weight. The hybrid technology is susceptible to inbreeding. It was developed for closed circuit farming in the Netherlands, and Dutch farmers seem not to easily accept the sterile genetics.[178] Nevertheless, the Dutch company representative propagated the hybrid (called *Heteroclarias*) as having great potential to establish catfish hatcheries with various scales of production in African countries.[179]

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[175] http://www.worldwildlife.org/what/globalmarkets/aquaculture/dialogues-pangasius.html (accessed 7/10/2009)
[176] Nguyen Hong Nguyen and Raul W. Ponzoni (2008): Prospects or Development of a Genetic Improvement Program in African Catfish (Clarias Gariepinus) in: Ponzoni, R.W. and N.H. Nguyen (eds). Proceedings of a Workshop on the Development of a Genetic Improvement Program for African catfish Clarias gariepinus. WorldFish Center Conference Proceedings Number 1889. The WorldFish Center, Penang, Malaysia. 130 p.
[177] Gamal El-Naggar The African Catfish Clarias Gariepinus: A Perspective on its Role and Potential in Egyptian Aquaculture. In: Ponzoni, R.W. and N.H. Nguyen (eds). 2008. Proceedings of a Workshop on the Development of a Genetic Improvement Program for African catfish *Clarias gariepinus.* WorldFish Center Conference http://www.worldfishcenter.org/resource_centre/WF_1101.pdf (accessed 7/10/2009)
Proceedings Number 1889. The WorldFish Center, Penang, Malaysia. 130 p.
[178] Hans Komen Small scale breeding programs: the experience from the Netherlands www.aquabreeding.eu/LinkClick.aspx?fileticket=5Qu1RRIMVGA%3D&tabid=98&mid=437&forcedownload=true (accessed 7/10/2009)
[179] Willy Fleuren, Reproductive and Grow Out Management of African Catfish in the Netherlands, in: Ponzoni, R.W. and N.H. Nguyen (eds). 2008. Proceedings of a Workshop on the Development of a Genetic Improvement Program for African catfish *Clarias gariepinus.* WorldFish Center Conference Proceedings Number 1889. The WorldFish Center, Penang, Malaysia. 130 p.

5 Corporatization of aquaculture seed sources

In 2004, it was estimated that only 5-10 % of the total aquaculture production was based on seed delivered by the genetics industry.[180] The following chapter, before describing some private genetics companies, explains where aquaculture farmers in Asia, Latin America and Africa get their seeds from. Nowadays, collection from the wild has largely been replaced by hatchery production. The data are mainly derived from two recent publications, by FAO on 21 selected countries,[181] and by Worldfish, on 9 Asian countries.[182]

Asia: From decentralized hatcheries to foreign investment
In Asia, the spectacular performance of the aquaculture sector was facilitated by research and development systems in which the public sector played a prominent role.[183]

Aquaculture genetics and breeding research in the largest producer country, **China**, is a mainly public activity. The Chinese Fishery Academy has several thousand employees, and more than 200 public fisheries research institutes.[184] There are more than 15,000 extension staff to spread new technologies. Large state-owned farms usually run carp hatcheries; hatcheries for freshwater crabs and prawns are often operated by private farms; and commercial companies or research institutes often operate marine fish hatcheries.[185]

In **India** and **Bangladesh**, the public sector previously provided the investment for hatcheries operation, while commercial production and marketing of the fingerlings were undertaken by the private sector. However, since the 1990s, the private sector has participated in the propagation of hatcheries and today a major supply of fry comes from the private sector. They include small-scale (backyard) and integrated rice-fish in the paddy field technology, as well as medium- to large scale hatcheries. Freshwater hatcheries are typically small-scale operations whereas the brackish water and marine hatcheries are usually operated at a large scale.

In **India**, fish seed production started with state support, but it has now developed into a major sub-sector of the aquaculture industry with large private sector participation, mostly in the hands of the small-scale producers. Shrimp seeds, however, are produced by large private companies or in partnership with government agencies. Although most farmers procure fish seed directly from the seed producers, seed traders have been emerging as a major source during the last five years. Sometimes, large-scale fish operators purchase seeds in bulk for sale to fellow farmers. West Bengal is the hub of seed production, supplying seeds to Bihar, Uttar Pradesh and even up to Punjab. Andhra Pradesh is one of the leading states supplying fish seeds to neighbouring states through private seed producers.
In **Bangladesh**, hatchery development began in the early 1970s, when government owned hatcheries began producing quality seed through artificial breeding. By 1988, there were a

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[180] Gjedrem, T. 2005. Presentation at the Fish Breeders Round Table, 16 June 2004. Cited after: Rosendal, G. Kristin, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2006): Access to and Legal Protection of Aquaculture Genetic Resources: Norwegian Perspectives. Journal of World Intellectual Property, Vol 9, No 4, 2006, pp. 392-412.
[181] Bondad-Reantaso, M.G. (ed.) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p.
[182] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p.
[183] ibid.
[184] ibid.
[185] ibid.

total of 239 hatcheries, and by 1998, the number rose to 776, a large number of which were small-scale privately owned hatcheries.
Malaysia has two specialized government hatcheries and 195 private hatcheries.[186]
Viet Nam produces seeds artificially for most of its traditional freshwater cultured species and is therefore able to meet most of the seed demand of its aquaculture industry from its more than 447 hatcheries.[187]

FAO stated that in Asian countries, the focus has shifted from centralized to decentralized seed production, a strategy which offers opportunities for poor farmers to enter into the fish seed business. Decentralized fish seed production should be supported by appropriate breeding strategies to maintain the genetic quality of broodstock. Building support services at the local level is crucial in expanding fish seed supply. In Asia, even though seed of major cultivated species are produced in sufficient quantities in hatcheries, poor quality is perceived as a major constraint to expansion of freshwater aquaculture. Several approaches ranging from institutional to farmer managed decision-making tools have been adopted by countries and farmers to assure fish seed quality.[188]

But the shift towards decentralized small hatcheries may be threatened. Foreign investment in hatcheries is active in India, Indonesia, Malaysia, Thailand Viet Nam, according to the WorldFish Center,[189] and the relevant North American shrimp genetic industry is described further below (Moana in Viet Nam, Thailand and India; HighHealth Aquaculture in Thailand and Indonesia; Syaqua in Thailand). In the Philippines after lifting of a Pacific White shrimp ban, seven US breeding companies were, in January 2007, approved to multiply Pacific White shrimp.[190] By 2008, the Pacific White Shrimp reached already 12,5 percent of the Philippines market.[191] The Norwegian AKVAFORSK is cooperating with an Indian research institute on selective breeding for White Spot resistance. The Norwegian policy to privatise public aquaculture research results (see AquaGen) may lead to private shrimp hatchery investment from Norway.

Latin America: From the wild to foreign investment
As the aquaculture sector grew and turned into an export-oriented industry, private investment has been channelled into seed production, sometimes or as a part of vertically-integrated aquaculture ventures. Seed quality (i.e. survival, growth rate, disease resistance, size uniformity) is not regulated by governments. However, with increasing international seed trade, regional hatcheries are introducing quality assurance measures. The only type of certification that is common to all countries of the region is an official zoosanitary certificate that is mandatory before domestic and international movement of seed can take place. Given the rapid expansion of export-oriented farming of high-value species, it is expected that both volume of high quality seed and quality certification procedures will gradually be in place throughout the region.[192]

[186] ibid.
[187] USDA Vietnam Fishery Products Annual Report 2007 http://www.fas.usda.gov/gainfiles/200707/146291702.pdf (accessed 7/10/2009)
[188] Bondad-Reantaso, M.G. (ed.) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper No. 501. Rome, FAO. 2007. 628p.
[189] Dey, M.M., R.M. Briones, Y.T. Garcia, A. Nissapa, U.P. Rodriguez, R.K. Talukder, A. Senaratne, I.H. Omar, S. Koeshendrajana, N.T. Khiem, T.S. Yew, M. Weimin, D.S. Jayakody, P. Kumar, R. Bhatta, M.S. Haque, M.A. Rab, O.L. Chen, L. Luping and F.J. Paraguas. 2008. Strategies and Options for Increasing and Sustaining Fisheries and Aquaculture Production to Benefit Poorer Households in Asia. WorldFish Center Studies and Reviews No. 1823. The WorldFish Center, Penang, Malaysia. 180 p.
[190] http://www.bfar.gov.ph/download/fao/FAO225-1.pdf (accessed 7/10/2009)
[191] Aquaculture Asia Pacific Volume 4, Number 2 March/April 2008
[192] Bondad-Reantaso, M.G. (ed.) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p.

Africa: Potential for foreign investment

In Africa, availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture. Government hatcheries have generally failed to serve aquaculture farms. At present, the main aquaculture species in the continent are Nile tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepinus*). While the tilapias are easy to reproduce on-farm, poor broodstock management had resulted in reduced growth rates. Catfish are mostly reproduced in hatcheries, but availability of broodstock and high mortality rates in larvae are key problems. Egypt and Nigeria have the highest number of commercial hatcheries, although most of these are unregulated and lack accreditation and certification systems. Ghana, Cameroon, Uganda and Zimbabwe rely almost entirely on semi-commercial systems producing unreliable quantities and quality of seed.[193]

Genetically male tilapia[194] is sold by a Dutch company in Nigeria, Ghana, Togo, and Benin. According to Fishgen Ltd, which has a trademark, genetically male tilapia are produced in a simple breeding programme combining sex reversal and progeny testing which does not involve any genetic engineering techniques. Genetically male tilapia are not considered as GMOs according to legal standard definitions. However, genetically male tilapia is a technology that prevents aquaculture farmers from reproducing and makes them return to the fry or fingerling provider for the next generation.

Aquaculture in Africa, and especially genetic research, is high on the agenda of mainstream development financing agencies and policy makers.

Europe and North America: Formation of corporations

Looking at recent history of industrialized countries, aquaculture (similar to livestock breeding) was taken from public research organizations into private companies. In Western Europe and Northern America, breeding of salmon is entirely private; however, the companies often retrieved their genetic resources and knowledge from public research organizations. With regard to trout, only Finland and partly Denmark still have public breeding organisations. In transition countries, aquaculture breeding is still a public activity. For carp, there are several public breeding programmes in Eastern Europe.

This does not mean that aquaculture breeding research is privately funded. In contrary, public funding in aquaculture has probably increased with the increasing economic role of aquaculture. The data provided on genetic companies further below mention some examples.

There are various sizes and levels of integration of the aquaculture genetic industry. There are companies that integrate the keeping of parent stock, testing facilities, hatcheries, grow-out producer, processing, and retailing, like Marine Harvest. Others integrate fewer business components. The largest aquaculture genetics company, AquaGen AS, was in 2008 itself integrated in the world's largest poultry genetics company, EW Group.

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[193] Bondad-Reantaso, M.G. (ed.) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p.

[194] See Fishgen Ltd http://www.fishgen.com/3What%20is%20GMT.htm (accessed 7/10/2009)

Formation of multi-species corporations 2005 - 2008

- 2005: Genus plc set up to combine global market leaders of pig and cattle genetics
- 2007: Hendrix Genetics (layer, broiler) bought Nutreco's breeding section (broiler, turkey, pig; in 2008, Hendrix Genetics bought France Hybrides (pig)
- **2008: EW Group (layer, broiler, turkey) acquired the salmon and trout breeder Aquagen**
- 2008: Groupe Grimaud (poultry) founded Pig Genetics Development Company and bought share of Newsham's (former Monsanto's) pig business.

Source: Susanne Gura (2009): Corporate livestock farming: A threat to global food security. In: Third World Resurgence 223, Kuala Lumpur

Market penetration of aquaculture genetics companies in the North is already very high (around 70 percent in salmon and trout seed). Through mergers and acquisitions, exclusive business models and forward contracts (that bind customers in future), their market power is increasing. Integration in multi-species genetics corporations is likely to add to the market power. In plant and livestock genetics, similar processes have led to high genetic uniformity, high damages from diseases, and pesticide and herbicide use. Smallholders have become more indebted due to high cost of seed, and more dependent on market dominating corporations.

Market domination and penetration

In plant seeds, ten corporations dominate 55 percent of the global market. Global market domination is exceptionally high in poultry genetics, e.g. 60 percent in egg layers, and fast increasing in pig and cattle genetics. Many national markets are already dominated by one or two corporations. Aquaculture genetics is likely to follow. Further mergers and acquisitions can be expected. Where available,(1) business data show that the genetics industry's profits are growing, even when the agricultural sector is in crisis. Exclusive business models and forward contracts (that bind customers in future) certainly contribute considerably to their increasing market power.

Globally, one third of pigs, half of eggs, two thirds of milk and three quarters of broilers are produced with industrial breeding lines.(2) The market penetration of aquaculture genetics is comparable in industrialised countries, at around 70 percent in salmon and trout. In developing countries, industrial aquaculture breeding lines have reached some 3 percent, but nearly all mainstream development organisations have foreseen and recommended an increase

(1) No information is available on the business figures of the family owned corporations EW Group, Hendrix Genetics, and Groupe Grimaud

(2) FAO (2007): The State of the World's Animal Genetic Resources, Rome

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Salmon and trout genetics companies

AquaGen AS (Norway)/ Erich Wesjohann Group (EW Group, Germany)

The world's largest aquaculture genetics company is headquartered in Trondheim, Norway, with a representation in Chile, the main salmon farming area after Norway and UK.[195] AquaGen's main products are fertilized eggs of Atlantic salmon and rainbow trout, and it holds a global market share of 35 %.[196] Aqua Gen's turnover recently more than doubled within two years, from € 13 million in 2005 to € 27 million in 2007.[197]

In early 2008, the majority of the shares of Aqua Gen were bought for around € 60 million[198] by the EW Group. EW stands for Erich Wesjohann, and the Germany-based family owned company EW Group is the world's largest poultry breeder. EW Group is global market leader in the genetics of white egg layer hens (global market share of 68%) as well as the genetics for broiler and turkey.[199] The other main shareholders are two international fish feed companies (Skretting AS and Cermaq ASA) and Marine Harvest AS, all based in Norway.[200]

AquaGen's genetic material originates from the public research organization Akvaforsk (now NOFIMA); the scientists had collected wild Atlantic salmon from several Norwegian rivers and initiated a salmon breeding program in the early 1970s. Similarly, a rainbow trout breeding program started with collections from rivers in Norway, Sweden and Denmark. In 1985, a commercial breeding and egg producing company was set up and a copy of all Atlantic salmon and rainbow trout families from Akvaforsk AS were transferred at no cost. Breeding is focused on selection from some 160 salmon and trout families, for traits like fast growth, fillet quality, and disease resistance. Industry, government, bank/insurance and equipment providers invested in the company from the early nineties. In 1999 the name of the company, then Norwegian Salmon Breeding AS, as well as its profile, was changed into AquaGen AS.[201]

Frozen milt technology was developed to improve preservation of male fish genetic material. This way, the families in the four different age cohorts (Atlantic salmon has a generation cycle of four years) collected during the 1970s were merged into one breeding nucleus. Freezing of gene material also serves to conserve genetic diversity in gene banks, and AquaGen is co-owner of the private BioBank AS located in Hamar, Norway.[202] The company recently increased the number of salmon families and breeding candidates to some 800 families. Regarding trout, 200 families have been collected and selected over ten generations (30 years).[203]

Laboratory routines for mapping of genetic markers and QTL's have been established at the public research organization Akvaforsk, that has access to fish individuals with pedigree information from

[195] Chile's aquaculture industry based on introduced salmonids produces approximately 20 percent of the world's farmed salmon and directly employs approximately 30 000 people. http://www.fao.org/fishery/topic/13531/en (accessed 7/10/2009)
[196] http://www.privateequityeurope.com/public/showPage.html?page=344703&tempPageName=663355 (accessed 7/10/2009)
[197] http://www.nortrade.com/index.php?cmd=company_presentation&companynumber=653059 (acc.7/10/2009)
[198] http://investing.businessweek.com/research/stocks/private/snapshot.asp?privcapId=13529426 (acc 7/10/2009)
[199] Susanne Gura (2007): Livestock Genetics Companies. Concentration and proprietary strategies of an emerging power in the global food economy. League for Pastoral Peoples and Endogenous Livestock Development, Ober-Ramstadt, Germany
[200] http://www.aquagen.no (accessed 7/10/2009)
[201] ibid
[202] http://www.bio-bank.no/engelske_sider/index_eng.php (accessed 7/10/2009)
[203] http://www.aquagen.no/En/Products/ (accessed 7/10/2009)

AquaGen.[204] Large statistical analyses of data on genetic markers are needed, and the company is collecting data for 22 traits from about 100,000 individuals each generation.

The company offers all-female batches of rainbow trout in order to improve profitability of farmers, since early maturing male fish quality does not sell. At the same time, this technology prevents others from using the animals for breeding.

With regard to genetically modified (GMO) fish, AquaGen itself does not report activities or a policy on its website. Its research partner, Akvaforsk/NOFIMA, underlines the unpredictability of the current methodology. "The gene construct is integrated at random locations and in random numbers of replicates in the chromosomes, and this seems to affect the action of the gene construct and other, natural genes. Furthermore, gene transfer seems to be less efficient in populations that have already been genetically improved by traditional methods. However, Akvaforsk has relevant in-house experience and stands ready for action as soon as commercial application of GE fish is within view."[205]

AquaGen AS is GLOBAL GAP and FREEDOM FOOD-certified.[206]

Marine Harvest ASA (Norway)
Marine Harvest AS (Norway) is with 25% of the farmed salmon, the global market leader and the largest seafood company. It produces its own egg supply, some 1100 million eggs per year. The company has some 7500 employees and is listed on the Oslo Stock Exchange. The revenue is Euro 1.585 billion. A three year contract between WWF-Norway and Marine Harvest was signed in 2008 whereby WWF-Norway will employ a full-time marine conservation officer in order to significantly reduce the ecological footprint and environmental effects of Marine Harvest's operations.[207]

Aqua Bounty Technologies Inc. (USA)
Aqua Bounty Technologies Inc., based in Waltham, Mass., USA, was initially established in 1993 as a division within A/F Protein, a biotechnology company specializing in products that exploit antifreeze proteins.[208] The company was in 1999 the first to have applied for market approval of GMO fish. The transgene was developed for rapidly growing salmon, trout and other finfish.
The company has a Canadian subsidiary, running a large salmon hatchery, where it grows GMO salmon to be ready for marketing in 2009. Being certified disease-free, it could export fish eggs, milt and fry. Another product, the immune booster IMS, was given up in 2008, due to regulatory as well as marketing problems.[209] Earlier, IMS had been approved in Mexico and Ecuador. To continue research work on Antiviral dsRNA, an agent against the White Spot Virus, an economically destructive disease for the shrimp farming industry, the company end 2008 received a $100,000 grant from the National Science Foundation.[210]
By 2005, the company had incurred net losses of approximately USD 19.9 million. Aqua Bounty Technologies Inc. is listed in the London Stock Exchange.[211] In January 2009, its Canadian branch received a CN$2.9 million grant from the public Atlantic Canada Opportunities Agency to develop sterile salmon.[212]

Troutlodge Inc. (USA)
Troutlodge Inc, founded in 1945 is the world's leading supplier of eyed (fertilized) salmonid eggs, including all-female and triploid trout eggs of rainbow trout. It annually ships nearly 400 million eggs to

[204] http://www.akvaforsk.no (accessed 7/10/2009)
[205] ibid
[206] http://www.aquagen.no (accessed 7/10/2009)
[207] http://www.marineharvest.com/en/Investor1/Press-releases/2008/WWF-Norway-teams-up-with-Marine-Harvest-Partnership-for-sustainable-aquaculture/ (accessed 7/10/2009)
[208] http://www.aquabounty.com/history.html (accessed 7/10/2009)
[209] Reuters UK. Aqua Bounty waits on approvals for shrimp booster (http://investing.reuters.co.uk/news/articleinvesting.aspx?type=companyOutlooksNews&storyID=2007-03-09T073007Z_01_L09332448_RTRIDST_0_AQUA-BOUNTY-TRADING.XML). March 9, 2007. (acc.7/10/2009)
[210] http://www.aquabounty.com/2008-Operations_Update_YE.pdf (accessed 7/10/2009)
[211] http://www.aquabounty.com (accessed 7/10/2009)
[212] ACOA News Release *23 January 2009*
http://mediaroom.acoa-apeca.gc.ca/e/media/press/press.shtml?4266 (accessed 7/10/2009)

over 50 countries. Based in Washington, USA, it also has facilities in Chile (Quetro SA) and UK. 20% of egg sales are triploid. Unfertilized eggs are available for research purposes.
The company in 2007 moved into marine aquaculture species and land-based marine aquaculture when it bought Unlimited Aquaculture LLC with facilities in Hawaii. It produces the fast growing Butterfish (*Anoplopoma fimbria*, also known as Sablefish and Black Cod), under a brand name and will also sell fingerlings.[213]

Troutex ApS (Denmark)
A new company was formed in 2007 in Denmark, on the basis of a research programme financed by the Danish Government, the Scientific Research Board of Agriculture and Veterinary Science, and the Danish Ministry of Fisheries. Further financial support for a large hatchery came from a joint venture of the Danish aquaculture associations and the Danish Ministry of Food, Agriculture and Fishery. Troutex is planned to sell 40 - 60 million eggs per year.[214]

Aqua Seed Corporation (USA)
AquaSeed Corporation, established in 1988, sells 10 million eyed eggs per year of Pacific salmon. Based in Seattle, USA, It has developed pedigrees of 40 distinct families over 15 generations. The company is also involved in captive broodstock technologies for both wild and domesticated Pacific salmons, as the species is at risk and must be preserved. Pacific salmon populations have declined to such low levels in the Northwest region of the United States that the species was placed under the protection of the federal Endangered Species Act (ESA), requiring a comprehensive recovery effort.[215]

Shrimp genetics companies

SyAqua Research LLC
SyAqua is the world's largest breeder of Pacific white shrimp *Litopenaeus vannamei*, supplying nauplii, postlarvae and broodstock to shrimp farms. SyAqua was formed in 2002 by Sygen International plc, a company based in Berkeley, USA, that owned the largest global pig genetics supplier, PIC. A few months earlier, it had –together with several partners- received a research grant of US$8.2 million from the US Department of Commerce's ATP programme.[216]
In October 2002, SyAqua had acquired the assets of Mexico's largest shrimp breeding stock business, Super Shrimp, for US$4.5 million, and launched a genetic selection program for the Pacific white shrimp, *Litopenaeus vannamei*, in its nucleus breeding farm in Mexico.[217]
Brazil's leading shrimp breeding business, Aquatec, was bought in 2003,[218] and the company established a nucleus breeding facility in Thailand to open the Asian market for the Pacific White shrimp.
A research facility was started in Kentucky, USA, with a government grant of USD 2.8 million to develop saltwater shrimp biotechnology.[219] In California, the company opened a shrimp facility with the objective, among others, to "create genetic protection."[220]
End 2005, SyAqua was purchased as part of the Sygen group by Genus plc, a U.K based transnational livestock genetics company that combined the world's largest pig breeder with ABS, the world's largest cattle breeder. SyAqua management, however, spun off the aquaculture division with the businesses in Brazil, Thailand and Mexico.[221] From a hatchery on the island of Saipan, a USA territory in the Northern Marianas Islands, it supplies shrimp broodstock to hatcheries in Thailand and Indonesia.[222]

213 http://www.troutlodge.com/index.cfm?pageID=8CF4A892-3048-7B4D-A9CD8E6CFAB6785C (acc.7/10/2009)
214 http://www.troutex.dk/index.php?pid=1 (accessed 7/10/2009)
215 www.aquaseed.com (accessed 7/10/2009)
216 "Biosecure Zero-Exchange Shrimp Technology (BioZEST): A Paradigm Shift for the U.S. Industry"
217 http://www.syaquamexico.com/pdf/03.pdf (accessed 7/10/2009)
218 Emerging Markets Economy, Sep 17, 2003: SyAqua annomces deal with Brazil's leading shrimp breeding stock (accessed 7/10/2009)
219 March 31, 2005 Fishsite (accessed 7/10/2009)
220 Business Wire London Jan. 21, 2003 http://findarticles.com/p/articles/mi_m0EIN/is_2003_Jan_21/ai_96640527 (accessed 7/10/2009)
221 http://www.hemscott.com/news/static/tfn/item.do?newsId=51178830356235 (accessed 7/10/2009)
222 Now shrimp broodstock from Saipan. Aqua Culture AsiaPacific, Vol. 4, No. 2, p.45, March/April 2008

The company has incorporated several stocks and lines of distinct origins, which are invaluable genetic resources. The three shrimp lines that came with the Brazil subsidiary Aquatec, from Venezuela, Ecuador, and Panama, "were found to be nearly as genetically distinct from each other as the Chinese Meishan pig breed is distinct from the European pig breeds in general."[223]

The company's breeding schemes are modeled after the hybrid system of breeding corn and other plants, "that also provide assurances of genetic protection for SyAqua's improved stocks and investment efforts"[224], i.e. technologies that prevent the customers from further breeding but make them return to the company for a fresh supply of broodstock.
The company is a member of Carrefour's Quality Line program, and its hatcheries are certified by the Aquaculture Certification Council.[225]

Moana Technologies, LLC
Moana Technologies, LLC, is the largest Black tiger shrimp (*Penaeus monodon)* breeder. Founded in 2000 by the owner of the Belgian larval feed supplier INVE Group, the company is headquartered in Hong Kong and operates in six countries on three continents. The nucleus breeding center in Hawaii supplies the parent seed (postlarvae) to its own multiplication centers in Viet Nam, Thailand and India.[226] The multiplication centers grow the shrimp to adult size, breed them, hatch them and then sell postlarvae to farmers. In 2001, over 1,500 broodstock were brought to Hawaii from Asia and Africa. The breeding population consisting of several hundreds pedigreed and unrelated families is specific pathogen free.[227]

In India, the multiplication centre will have a production capacity of three billion post larvae (seed) a year to serve about 150,000 shrimp farmers across the country.[228] Further expansion is planned in Asia, Middle East, Africa and Latin America over the next years.[229]

Moana Technologies is involved in a research project at Vlaams Instituut voor Biotechnologie (VIB) in Belgium to develop GMO shrimps. [230]

High Health Aquaculture, Inc.
Established in 1994, High Health Aquaculture is located in the Aquaculture Park at the Natural Energy Laboratory of Hawaii Authority (NELHA) in Hawaii. The company is one of the largest shrimp broodstock suppliers, especially to Thailand and Indonesia. Specialized on "Specific Pathogen Free (SPF)" shrimps, it produces hybrid *Penaeus vannamei* broodstock, and is developing Black tiger shrimp *Penaeus monodon* as well as *stylirostris* broodstock.[231] The company received so far USD $1,000,000 in government funding;[232] its director Jim Wyban from 1984-1992, led the Marine Shrimp Farming Program of the U.S. Department of Agriculture.

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[223] Joao L. Rocha, Pedro Galetti, Ana Guerrelhas, Sarah Blott, Graham Plastow,
Daniel Ciobanu, and Hein van der Stehen (2005): Microsatellite-Based Assessment of Genetic Diversity and Variability in a Commercial Brazilian Shrimp Breeding Program. World Aquaculture Society, New Orleans, 2005
[224] http://www.syaqua.com/ (accessed 7/10/2009)
[225] ibid
[226] http://library.enaca.org/AquacultureAsia/Articles/Oct-Dec-2007/aa-oct-dec-07-moana.pdf (accessed 7/10/2009)
[227] http://www.shrimpnews.com/FreeNewsBackIssues/FreeNewsJuly200811.html; (accessed 7/10/2009)
http://www.aquaasiapac.com/issues/issue-nov_dec06.pdf (accessed 7/10/2009)
[228] Business Standard, November 20, 2008
[229] http://www.moanatech.com/corporate.php?h=2 (accessed 7/10/2009)
[230] http://vilt.westsite.be/nieuwsarchief/detail.phtml?id=17594 (accessed 7/10/2009)
[231] Interview in Shrimpnews.com Page 2 Feb 8 2008 (accessed 7/10/2009)
[232] http://www.hihealthshrimp.com/About.html (accessed 7/10/2009)

6 Aquaculture biotechnology, silver bullet of the genetics companies

At the beginning, this chapter summarizes some currently available aquaculture biotechnologies and their use – marker technologies and genome mapping. It then gives an overview over which GMO aquaculture species are available, what the status regarding market approval is, and associated food safety and environmental problems.

DNA Markers: Marking "property"

Tissue samples (typically of fin tissue) can be readily taken without killing the fish and easily and cheaply preserved for the medium to long term. DNA markers[233] can be used for traceability and intellectual property protection, and also to differentiate between different cultured stocks or between cultured and wild stocks. Such techniques can be applied to identify sources of escapes from aquaculture, to determine the impact of introductions or escapes of cultured stocks on wild stocks and to trace the origin of non-native farmed stocks. They can also be used to guide the collections from the wild to form base populations for aquaculture and breeding programmes, or to characterize genetic diversity in broodstock, among others.[234] There have been suggestions to establish the tracing by DNA fingerprinting nationally or even internationally, by making pedigree certificates mandatory for all hatcheries and grow-out farmers, for proprietary purposes of the genetics companies (see chapter 7).[235]

Marker Assisted Selection: Intensified selection for uniformity

Selective breeding with plant crops and livestock goes back to pre-historic times, and with the common carp several thousand years ago;[236] it started in other aquaculture species during the 1970s. The promoters of selective breeding are often cited[237] to be the Norwegian public organization Akvaforsk, a few smaller programmes in other species,[238] and the GIFT – Genetically Improved Farmed Tilapia – programme of the Philippines based WorldFish Center (former ICLARM). FAO promoted selective breeding for medium sized farms.[239]

Genetic markers are used for selective breeding, but, according to an FAO publication, they should best be combined with traditional selective breeding. Their use is expected to be for traits that can be measured only on the dead animal, e.g. fillet yield, and for traits that have low heritability.[240]

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[233] A genetic marker is a "genetic property for which there is an experimental procedure allowing identification of genotypes." Mair, G.C. 2007. Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome

[234] ibid.

[235] G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway

[236] FAO website

[237] e.g. Mair, G.C. 2007. Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome

[238] see Hulata 2001, cited after Mair, ibid.

[239] Tave, D. (1995) Selective breeding programmes for medium-sized fish farms. FAO Fisheries Technical Paper. No. 352. Rome

[240] Mair, G.C. (2007): Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome

Increasing intensity of selection will increase the problems where selection is prioritising growth parameters. In livestock, selection by conventional methods has already led to narrowing the genetic base down to levels considered dangerous for the survival of the breed, although millions of individual animals exist.

Genetic uniformity

- Cattle: in Holstein, Jersey, Brown Swiss breeds, the effective population size corresponds to less than 100 animals
  Only a few thousand bulls are evaluated each year
  Up to one million offspring per bull
- Pig: in Pietrain, Duroc, Hampshire breeds the effective population size is less than 100 animals
- Poultry: Trade secrets, no independent information available

New reproduction and selection technologies are leading to:

- Higher selection intensity (e.g. DNA marker assisted selection)
- Shorter generation intervals (e.g. embryo selection)
- More females than males in cattle and pig (“sexed semen”)
- Replication of the same (clones)

i.e. a faster increase in genetic uniformity

Source: Susanne Gura (2007): Livestock Genetics Companies. Concentration and proprietary strategies of an emerging power in the global food economy. League for Pastoral Peoples and Endogenous Livestock Development, Ober-Ramstadt, Germany

The dangers of selective breeding where productivity dominates selection cannot be over-emphasised. The cattle breeding industry is now looking to Norway, where cattle breeding was based on broader breeding goals and less uniformity for many decades. The Norwegian cattle breeding experience and the Red Scandinavian cattle gene pool may help to save the endangered industrial breeds. It must be added that in Norway, cattle breeding is still led by farmer organisations, while in most other countries, breeding is privatised. There are a few exceptions like India, Cuba, China and Vietnam. [241]

Genome mapping: Expensive disorientation

Genetic markers can be used to construct genetic maps (in which linked markers are assigned, using pedigreed matings, to linkage groups resulting in the assignment of chromosomal location, order, and distance between markers.)[242]

The objective of genome mapping is to locate a gene's position relative to that of other identifiable locations on a chromosome. This does not tell where on a chromosome a particular gene is actually found. Rather, it indicates the probability that it will be inherited along with other known points in the genome.

[241] FAO (2007): The State of the World’s Livestock Genetic Resources for Food and Agriculture, Rome

[242] Mair, G.C. (2007): Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.) Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome

The genomes of a number of aquaculture species have been or are being sequenced. In the US alone, the genomes of catfish, oysters, salmonids, shrimp, striped bass and tilapia are being sequenced under the National Animal Genome Research Program.[243] Genetic maps have been developed and published for four major species of e.g. shrimps including, *P. monodon, L. vannamei, P. chinensis,* and *M. japonicus*.[244]

Aquaculture geneticists envisions the mapping of more than 300 aquaculture species currently cultured, to be rather a financial, than a technical problem.[245] Per individual, not per species, genotyping costs amount to USD 200-400,[246] and thousands of individuals are needed.

However, not only the location, but also the function of the genes has to be established (functional genomics). Since a trait is rarely regulated by one single gene, the task of selecting for traits is complex. Genome-wide selection is under investigation in dairy cattle and poultry. Among aquaculture research institutes, at least NOFIMA/AKVAFORSK engages in genome-wide selection in salmonids.[247]

According to FAO, aquaculture genomics is developing rapidly and is seen as having many potential applications including

- marker-assisted selection for the genetic improvement,
- identification of fish genetic resources for their conservation and use, and
- the diagnosis and prevention of fish diseases.[248]

But how far has aquaculture genomics come? According to the introductory presentation of a recent international animal genomics conference, the genomic selection in animal breeding is generally slower than expected.[249] As usual, the researchers point to their constant need for more research.

For example, the largest salmon breeder, AquaGen, is collecting data on 22 traits from about 100,000 individuals each generation with biotechnological methods. The data are evaluated by a public research organization. Increased resistance to the infectious viral pancreatic disease is a trait that has been selected with QTL technology. A patent was granted in 2004 for the gene area which codes for proteins (MHC) and which is decisive for resistance against virus diseases in salmon and rainbow trout.[250]

In practice, however, the Chilean salmon industry, that is based on a few breeding programmes including AquaGen, has been almost wiped out by infections of sea lice and the Infectious Salmon Anaemia virus.

Public research funds have been allocated to genetically modifying aquaculture species, e.g. GMO shrimp that is disease resistant is being funded by the US Department of Agriculture's

[243] http://www.animalgenome.org/aquaculture/ (accessed 7/10/2009)
[244] L. Colombo (2007): Genetic Engineering in Aquaculture: Possibilities and Limitations. The International Symposium on Genetic Impacts from Aquaculture: Meeting the Challenge in Europe. Bergen, Norway 2-4 July 2007
[245] Zhanjiang (John) Liu (2008): Status and Trends of Aquaculture Genomics**,** World Aquaculture 2008; Zhanjiang (John) Liu (2007): Aquaculture Genome Technologies. Blackwell Publishing Ltd.
[246] Anna K. Sonesson, NOFIMA/AKVAFORSK: Genomic selection http://genomics.aquaculture-europe.org/fileadmin/Aquafunc/doc/Aquagenome_Workshop/18._Sonesson.pdf (accessed 7/10/2009)
[247] ibid.
[248] FAO Commission On Genetic Resources For Food And Agriculture (June 2007): The world's aquatic genetic resources: Status and needs, Rome
[249] André Eggen, INRA, France: Whole genome sequencing in livestock species : The end of the beginning? In: Animal Disease Genomics: Opportunities and Applications. 10th - 11th June 2008, University of Edinburgh, UK
[250] http://www.aquagen.no (accessed 7/10/2009)

National Research Initiative.[251] Public research funding policies should not ignore neither completely unresolved environmental problems nor the high reluctance of neutral bodies like the United Nations to expect GMO aquaculture species to contribute to food supply, let alone food security or poverty alleviation

Some lessons from GMO plant crops after two decades
Since more than a decade, genetically modified plant crops are being grown. Their usefulness to alleviate food security and poverty problems is increasingly contested. In contrary, assessments have found that the traits that have been transferred to "improve" crops are very limited. Around 80 percent of cultivated GMOs carry a specific herbicide resistance, i.e. they withstand the herbicides sold by the same corporations. Due to decreasing effectiveness, the two corporations (Monsanto and BASF) had to join their technologies, seeds now carry both transgenes. The majority of other transgene crops carry a natural pesticide from a bacterium (*Bacillus thuringensis*), thereby violating the basic rule of integrated pest management (apply the pesticide only when the pest surpasses a threshold). Pests are constantly exposed to the pesticide and become resistant to the pesticide. At the same time, the price of GMO seeds have been increased, sometimes to an extent that governments had to intervene.

Genetically modified aquatic species
Fish reproductive biology is much simpler than that of mammals, and the gene transfer methods are significantly more advanced. GRAIN reported that the first fast-growing transgenic fish, a common carp incorporating a mouse promoter gene linked to a human growth hormone gene, was developed in China already in 1986. By the end of last century, scientific teams from the US have genetically engineered carp and catfish, while British and Cuban groups have centred their efforts on tilapia and Canadian scientists have focused on salmon and trout.[252]

Some 35 different fish species are presently being genetically engineered, e.g. salmon, carp, trout, bass, sea bream, flunder, pike, catfish, loach and cod as well as on ornamental fish such as gold fish, zebra fish and spotted medaka.[253] A 2007 FAO publication summarized the state of the art in the following table, and mentioned that GMO research is decreasing.

The Oceanic Institute, Hawaii, USA, claims one of the first successful attempts to produce transgenic shrimp worldwide, in collaboration with University of Connecticut. A gene was transferred that codes for the synthesis of an antimicrobial peptide (cecropin). This "may provide a technology to produce disease-resistant shrimp quickly and effectively".[254]
GMO shrimps research is also done in Europe, involving the largest Black tiger shrimp breeding company, Moana Technologies LLC, at the Vlaams Instituut voor Biotechnologie (VIB) in Belgium.[255]

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[251] http://www.oceanicinstitute.org/nav.php?loc=research&page=nri_research&contentID=38 (acc. 7/10/2009)
[252] GRAIN The Seedling, December 1997
[253] Austrian Federal Ministry for Health, Family and Youth (November 2007): Transgenic Animals Status-quo in Relation to Risk Assessment and the State of Research
[254] Cecropins are a family of antimicrobial peptides that were first discovered in silk moth (*Hyalophora cecropia*) pupae. Due to their unique structural features, cecropins can be incorporated into cellular membranes of bacteria, fungi and parasites, resulting in the formation of pores on the membrane leading to the inevitable fate of death of pro- and eukaryotic pathogens. Source: http://www.oceanicinstitute.org/nav.php?loc=research&page=nri_research&contentID=38 (accessed 7/10/2009)
[255] http://vilt.westsite.be/nieuwsarchief/detail.phtml?id=17594 (accessed 7/10/2009)

The long list of GMO fish

Summary of transgenic fish being evaluated for aquaculture production indicating the nature of the transgene, the target trait and the location of the research (adapted from FAO, 2000)[256]

Species	Novel gene	Desired effect and comments	Location
Atlantic salmon	AFP AFP salmon GH	Cold tolerance Increased growth and feed efficiency	USA, Canada USA, Canada
Coho salmon	Chinook salmon GH + AFP	After 1 year, 10- to 30-fold growth increase	Canada
Chinook salmon	AFP salmon GH	Increased growth and feed efficiency	New Zealand
Rainbow trout	AFP salmon GH	Increased growth and feed efficiency	USA, Canada
Cutthroat trout	Chinook salmon GH + AFP	Increased growth	Canada
Tilapia	AFP salmon GH	Increased growth and feed efficiency; stable inheritance	Canada, UK
Tilapia	Tilapia GH	Increased growth and stable inheritance	Cuba
Tilapia	Modified tilapia insulin producing gene	Production of human insulin for diabetics	Canada
Salmon	Rainbow trout lysosome gene and flounder pleurocidin gene	Disease resistance, still in development	USA, Canada
Striped bass	Insect genes	Disease resistance, still in early stages of research	United States
Mud loach	Mud loach GH + mud loach and mouse promoter genes	Increased growth and feed efficiency; 2- to 30-fold increase in growth; inheritable transgene	China, Korea
Channel catfish	GH	33% growth improvement in culture conditions	United States
Common carp	Salmon and human GH	150% growth improvement in culture conditions; improved disease resistance; tolerance of low oxygen level	China, United States
Indian major carps	Human GH	Increased growth	India
Goldfish	GH AFP	Increased growth	China
Abalone	Coho salmon GH + various promoters	Increased growth	United States
Oysters	Coho salmon GH + various promoters	Increased growth	United States

Note: The development of transgenic organisms requires the insertion of the gene of interest and a promoter, which is the switch that controls expression of the gene.
AFP = anti-freeze protein gene (Arctic flatfish). GH = growth hormone gene

Higher productivity claims

A few species are being engineered for disease resistance and cold tolerance, but growth hormone gene transfer for growth enhancement is the predominant gene technology in

[256] Mair, G.C. 2007. Genetics and breeding in seed supply for inland aquaculture, pp. 519–547. In: M.G. Bondad-Reantaso (ed.). Assessment of freshwater fish seed resources for sustainable aquaculture. FAO Fisheries Technical Paper. No. 501. Rome, FAO. 2007. 628p. See also FAO (2003) . Genetically modified organisms and aquaculture, by Beardmore, J.A.; Porter, J.S. FAO Fisheries Circular. No. 989. Rome

aquaculture. GH-transgenes have been tried in many aquaculture fish species; however, dramatic increases in growth rates have been accomplished only in salmonid species. In trouts, large weight gain were achieved with transgene wild rainbow trout, but it did not work on domesticated strains,[257] so that transgene trouts are not likely to be developed for the market.

According to OECD, gene transfer is compromised by the fact that similar growth enhancement is achieved with conventional selective breeding.[258]

What does faster growth mean in terms of productivity? The example of backyard poultry economy in Viet Nam (see box) is questioning the competition for growth percentage reflected by the above table. Annual rates of return to investment of 600 percent would make poultry farm investors beam. A participation of 8 million beneficiary families would yield an award to a development policy maker, and no country leader would renounce to 5 percent of the Gross Domestic Product. These chicken lay "Golden Eggs," because, without public subsidies and at no external cost, they contribute to food security and alleviate poverty.

Productivity of smallholder poultry in Viet Nam
Backyard hens in Viet Nam lay 70 eggs per year, not 300 as their factory farm cousins do. Half of the eggs (35) are eaten by the family, and due to predators and other factors, only seven chicks reach selling age. The annual rate of return on investment is 600 %, as no costs are incurred. The risk is small, and the workload is small. Some 8 million families in that way earn around USD 50 million per year, corresponding to 5 % of the Gross Domestic Product.

Source: FAO (2006) http://www.fao.org/ag/againfo/foto/2006/flash/chickenani.html (accessed 7/10/2009)

GMO fish on a few markets, but not for food use
Ornamental fish with transgenes that make them glow in the dark, entered the markets first in Taiwan in spring 2003, and later in the USA, Mexico, the Dominican Republic and Trinidad and Tobago. When the genetically engineered zebra fish appeared in pet shops in other countries, they were withdrawn from the market. In the EU, transgenic aquarium fish require authorisation under Directive 2001/18/EC for import, sale and possession which was so far not granted. In Australia, the market approval of GE zebra fish is under review.[259] The U.S. Food and Drug Administration (FDA) determined not to formally regulate GloFish on the basis that tropical zebra fish pose no threat to the food supply, and the fact that there is no evidence that these genetically engineered zebra fish pose any greater threat to the environment than their widely sold unmodified counterparts.[260]

The first food derived from genetically modified animals has since long been predicted to be from salmon and served in the USA, but Aqua Bounty Technologies Inc. is since 1999 waiting for approval by the Food and Drug Administration of its trademarked salmon. This

[257] R. H. Devlin, C. A. Biagi, T. Y. Yesaki, D. E. Smailus, and J. C. Byatt, "Growth of domesticated transgenic fish," Nature, vol. 409, pp. 781-782, 2001
[258] OECD (2006): Abstracts of the OECD Workshop on the Biology of Atlantic Salmon (Salmo Salar)
[259] Austrian Federal Ministry for Health, Family and Youth (November 2007): Transgenic Animals Status-quo in Relation to Risk Assessment and the State of Research
[260] US Food and Drug Administration: www.fda.gov/bbs/topics/NEWS/2003/NEW00994.html (acc. 7/10/2009)

fish is a hybrid transgenic salmon with four linked copies of a salmon growth hormone to make it produce its own growth proteins year round, instead of only growing during the spring and summer months, reaching adult size in about 18 months instead of 24-30 months in case of a non-GE salmon.
Aquabounty started growing GMO salmon on a commercial farm in Canada for harvest in 2009, but is also investing in non-GMO technology in shrimp, aided by substantial public research funds.[261]

Food safety risk
As of end 2008, no genetically engineered fish had been approved for food. The US Food and Drug Administration released guidelines only in January 2009 that outline how genetically engineered animals will be regulated.[262]

Transgenic growth-enhanced tilapia and carp are also under regulatory review in Cuba and China,[263] respectively, but have so far not been approved.[264] According to a test based on the pathological principles of new medicines issued by the Ministry of Health of China, transgenic common carp is also approved safe for food, but not yet authorized.[265]

With regard to food safety, proponents argue that the manipulated growth hormone genes are not from different species and therefore transgenic fish is not different from conventional fish.[266] However, transgenesis is associated with major rearrangements and mutations in the host genome.[267] [268] Serious health impacts from transgenic food and feed have been documented,[269] and a recent study commissioned by the Austrian government showed that transgenic corn fed to mice significantly reduced their fertility.[270]

Some food safety administrations like the US Food and Drug Administration limit their perspective to human health risk when they process applications. Transgenic animals, however, create a whole range of risks, especially animal health problems, environmental problems, as well as social and economic problems since associated patents can lead to market domination. Transgenic plants have already contributed to diseases of pollinator insects, crop failures, farmer indebtedness resulting from high seed prices made possible by market domination of some seed companies, increased accidents due to increased herbicide use (many GMO crops are herbicide resistant), among other problems.

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261 http://www.aquabounty.com/pressarchive.html (acc. 7/10/2009), see also the chapter on genetics companies
262 www.fda.gov/cvm/GEanimals.htm (accessed 7/10/2009)
263 Gang Wu, Yonghua Sun and Zuoyan Zhu (2003): Growth hormone gene transfer in common carp. In: Aquat. Living Resour. 16 (2003) 416-420
264 M. Flajšhans and G. Hulata (2007): Common carp - Cyprinus carpio. http://genimpact.imr.no/__data/page/7650/common_carp.pdf (accessed 7/10/2009)
HU Wei, WANG YaPing & ZHU ZuoYan (2007): Progress in the evaluation of transgenic fish for possible ecological risk and its containment strategies. In: *Sci China Ser C-Life Sci* | Oct. 2007 | vol. 50 | no. 5 | 573-579
265 Gang Wu, Yonghua Sun and Zuoyan Zhu (2003): Growth hormone gene transfer in common carp Aquat. Living Resour. 16 (2003) 416-420
266 L. Colombo (2007): Genetic Engineering in Aquaculture: Possibilities and Limitations. The International Symposium on Genetic Impacts from Aquaculture: Meeting the Challenge in Europe. Bergen, Norway 2-4 July 2007
267 Ho MaeWan, Living with the Fluid Genome , ISIS/TWN, London/Penang, 2003 (accessed 7/10/2009)
Wilson AK, Latham JR and Steinbrecher RA. Transformation-induced mutations in transgenic plants. Analysis and biosafety implications. Biotechnology & genetic engineering reviews 2006, 209-237.
268 Joe Cummins and Mae-Wan Ho (2008): Transgenic Animals for Food Not Proven Safe. Institute of Science in Society Press Release 17/11/08 http://www.i-sis.org.uk/TAFNPS.php (accessed 7/10/2009)
269 Ho MaeWan, GM is Dangerous and Futile. Science in Society 40
270 Velimirov A, Binter C and Zenteck J. Biological effects of transgenic maize NK603xMON810 fed in long term reproduction studies in mice. Report, Forschungsberichte der Sektion IV, Band 3. Institut für Ernährung, and Forschungsinttitut für biologischen Landbau, Vienna , Austria , November 2008

Environmental risk

The most discussed risk with genetically engineered fish is environmental.[271] A number of fish species are held in cages, and hardly anybody contests nowadays that escapes are frequent. Other than in livestock, where escapes do not frequently occur[272] and wild relatives –with exceptions- are less common, the risk of GM fish contamination is extraordinarily high.[273]

> **Escapes of salmon**
>
> Around 0.5-2 million salmon (0.5-1.6% of production) escape each year into the North Atlantic, around 50% of the wild pre-fishery abundance in the region, despite close regulation of farming. Numbers of sexually mature farm salmon escapees returning to rivers in the 1980s and 1990s ranged from 200,000-300,000 and composed up to 80% of salmon in some Norwegian rivers. Escapes generally enter rivers, near to their farm of origin, but some may do so hundreds of kilometres away, where many interbreed with wild fish, with farm females generally more successful than farm males and more hybrid than pure offspring produced. Escapes of juveniles from hatcheries and freshwater cages occur in some areas but their numbers and impact are poorly documented. Both can cause direct genetic effects on wild populations.
>
> *Source: Ashie Norris, Marine Harvest Ireland: Review on Breeding and Reproduction of European aquaculture species: Salmon Salar. Report on EU funded programme Aquabreeding, January 2008*

But whether there are no differences between the biodiversity risks from escapes of GMOs and from conventionally bred fish or (in some respects) from exotic species, as claimed by OECD,[274] is not yet proven.

The risk of transgenic contamination of wild relatives has two sides, it was argued at a European Symposium in Norway in 2007:[275]

- If the GMO species are indigenous, they would threaten their wild relatives with extinction, as outlined in the often cited Trojan gene hypothesis by Muir and Howard. GMO fish grow faster and males reach a size where they compete for mating before being sexually mature.[276] With the loss of wild populations, aside from environmental damages, there is a serious impact both from and on aquaculture. Genetic diversity including resistance and other features valuable to future farmer generations may get lost.
- If the escaped GMO species are, however, alien, as could be the case of common carp in Africa or tilapia in Asia and South America, only non-genetic impacts on other

[271] e.g. in FAO (2000): Electronic Forum on Biotechnology in Food and Agriculture. How appropriate are currently available biotechnologies for the fishery sector in developing countries ? http://www.fao.org/biotech/logs/C4/summary.htm (accessed 7/10/2009)
[272] However, in livestock, disease vectors could easily escape from farms and affect wild species.
[273] van Aken, J. (2000). “Genetically Engineered Fish: Swimming Against the Tide of Reason”. Greenpeace International, Amsterdam
[274] OECD (2006): Abstracts of the OECD Workshop on the Biology of Atlantic Salmon (Salmo Salar)
[275] L. Colombo (2007): Genetic Engineering in Aquaculture: Possibilities and Limitations. The International Symposium on Genetic Impacts from Aquaculture: Meeting the Challenge in Europe. Bergen, Norway 2-4 July 2007
[276] (Transgenic Res., 11, 101-114, 2002); spread to the general public by Greenpeace International (October 2004): Genetically Engineered Fish - New Threats to the Environment

species would be possible. High environmental risks are associated with freeze tolerant GM salmon. This trait may help salmon invade habitats in the northernmost environments that so far have been spared from the effects of aquaculture.[277]

In November 2008, a discussion group was organized by the Secretariat of the UN Convention on Biological Diversity, in order to prepare biosafety negotiations. It was stressed that data are missing on basic biology, physiology and ecology of many of the fish species, that risk assessment is a very complex task.[278]

The GMO crop industry has set an example of how corporations are not ready to compensate for any damages from contamination (see box). There is an international agreement that regulates liability and redress of damages caused by internationally traded GMOs (called LMO, living Modified Organisms in that agreement), the Biosafety Protocol (also know as Cartagena Protocol) under the Convention on Biological Diversity.

A proposal by the GMO crop industry to redress GMO contamination damage

216 cases of contamination have been recorded in 57 countries over the past ten years.(1)

The genetic engineering industry has proposed a voluntary fund whereby six GMO crop producing companies (Monsanto, DuPont/Pioneer, Syngenta, Dow AgroSciences, Bayer, BASF) would provide compensation for cases of significant damage to biological diversity, on terms provided in a Compact, among others:

- If a GMO is authorized and the GMO is used as intended, yet damage still results, then industry is indemnified.
- A 25-year baseline of data is required to compare against potential damage (which will rarely be achievable)
- Damages are excluded that were assessed by the importing countries (although countries have with their Biosafety Protocol membership a duty to assess risks)
- Claims by farmers for costs or lost profits are practically excluded
- Confidentiality is required of all evidence and proceedings (no transparency).(2)

Sources:
(1) Genetic Modification Contamination Register Report by GeneWatch UK and Greenpeace International, http://gmcontaminationregister (accessed 7/10/2009)
(2) Greenpeace Briefing "The Revised Proposed Industry Compact Assessed", January 2009.org (accessed 7/10/2009)

Proponents are pushing for field releases, since tests in secluded environments would be of limited significance and moratoria endless; one could not leave GE fish "only an impressive lab invention." Sterility of GE fish is praised as the solution, especially since several options are at hand. They all are not reliable, but combining two imperfect sterilization technologies is suggested to "fill up the gap in its per cent effectiveness."[279]

277 OECD (2006): Abstracts of the OECD Workshop on the Biology of Atlantic Salmon (Salmo Salar)
278 http://bch.cbd.int/onlineconferences/lmofish_ra.shtml (accessed 7/10/2009); William M.Muir: The threats and benefits of GM fish. A generally accepted model for assessing the environmental risk of GM organisms would not only help regulators but also address fears about this technology EUROPEAN MOLECULAR BIOLOGY ORGANIZATION EMBO reports VOL 5 | NO 7 | 2004
279 L. Colombo (2007): Genetic Engineering in Aquaculture: Possibilities and Limitations. The International Symposium on Genetic Impacts from Aquaculture: Meeting the Challenge in Europe. Bergen, Norway 2-4 July 2007

Needless to mention that the aquaculture GMO researchers along with the industry have a common objective, which is the same as for GMO crops, to feed the growing hungry populations in the world.[280]

The contrary may be the case. Three examples how GMOs can drive farmers deeper into poverty:

1. Market domination could be fostered by GMOs: By cashing in on royalties, companies accumulate capital and secure revenue opportunities, and thus become a party of mergers and acquisitions. Market domination in vital markets like seeds could make farmers depend on single companies. For example, the government of the Indian state of Maharashtra intervened when Monsanto's Indian subsidiary Mahyco raised GMO cotton seed prices to an extent that farmers could not break even. Other seed alternatives were no longer available due to market domination.

2. GMO cotton farmers in the same State of Maharashtra had little choice but to grow the herbicide resistant GMO cotton. The yield was far less than promised, and the cost of seed and associated herbicide had driven many farmers into indebtedness. Their only way to relieve their families from debt was suicide.

3. Farmers could be sued for not paying royalties if their shrimp or fish is found to carry proprietary genes – GMOs are almost always patented. This happened to some 90 US farmers, among which the famous Percy Schmeiser from Saskatchewan. Their canola farms were contaminated by Monsanto's GMOs.

[280] Barb Glenn, Biotechnology Industry Organization: "Bio-Ag: Key to Feeding a Hungry World". Arizona Cure, October 14, 2008

7 Proprietary arrangements: "The Rings of Protection"

How to keep prices high? How to bind the customers? How to prevent others from copying? These universal business questions are answered by aquaculture genetics companies in special ways that go far beyond business strategies of other genetics companies. Customers will buy from trusted and renowned sources. But the genetics industry is greedy for more, and sterility biotechnologies make it possible. Such technologies are not reliable enough to protect biodiversity from escaped breeds, but enough to make customers return to the breeder for fresh supplies of brood stock instead of hatching the next generation themselves. Such proprietary strategies help the corporations increase their revenues as well as their market shares and dominate markets, for example the multi-species livestock genetic corporations. It is not only likely that aquaculture genetics will become part of these corporations; the first such case is a reality since February 2008.[281]

Proprietary strategies: Why and how?

A study by the Norwegian Fridtjof Nansen Institute and Akvaforsk (the research institute from which the world's largest salmon breeding programme was privatized) looked into various proprietary strategies. The objective of these strategies is to "encourage the users of their genetic material to deal directly with the program."[282] To translate the industry friendly jargon: Proprietary strategies are to prevent the customers from using the animals for more than one generation, or from running their own breeding programme on the basis of those animals.

According to the Akvaforsk/FNI study, aquaculture genetics companies limit by contract how their customers (usually multipliers/hatcheries) may use the fertilized fish eggs. Neither further sale for breeding nor reproduction are allowed. The study points out that anyway the reproduced fish will then lag behind by at least one generation compared to the fertilized eggs supplied directly by the genetics company. The competitive advantage of the genetics company is no more than one generation, and the pressure of competition would be high. Thus, the aquaculture genetics companies could mark their products, make them traceable, and have a legal system that ensures property and enforcement. [283] Traceability technologies are being developed; legal enforcement, however, is a costly path. Alternatively, the complete in-house production chain from genetics until processing could be integrated into the business, a path that e.g. Marine Harvest AS is taking. The option of specialised genetics companies is to sell either sterile or "monosex" juvenile animals, so that the grown out animals will not reproduce.

Terminator technologies in aquaculture

For plants, a variety of gene transfer technologies is available that render them sterile. If applied, farmers would be compelled to return to the company to buy seed instead of saving seeds from their harvest for the next season. The proponents argue that sterility would prevent contamination with GMOs, a problem that has already occurred in several crop species.

For a number of important reasons, the United Nations are maintaining a moratorium, a temporary ban, on these "Genetic Use Restriction Technologies (GURTs)."[284] Socioeconomic

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[281] Susanne Gura (2008): Concentration in the livestock genetics industry. Presentation at NCCR Trade Regulation IP-9 Workshop "Animal Breeding, Innovation, Trade and Proprietary Rights." World Trade Institute, Berne, 27-28 November 2008

[282] G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway

[283] ibid.

[284] CBD COP V (2000), Decision 5, Section III (http://www.cbd.int/convention/cop-5-dec.shtml?m=COP-05&id=7147&lg=0) (accessed 7/10/2009), reaffirmed by COP VIII (2006)

reasons for the ban include rising cost for seed and a total dependency on seed corporations, not only of farmers, but also whole countries. The fact that GURTs are not totally reliable technologies renders the argument invalid that GURTs could control GMO contamination.

Aquaculture geneticists argue in the same way, that terminator technology, besides serving proprietary purposes, would control the contamination of wild populations by fish escapees.[285]

Genetic use restriction technologies in aquaculture species can be grouped in 1) techniques to produce monosex populations, and 2) techniques to increase the number of chromosome sets of the genome.[286]

Monosex populations: Benefit guarantee for genetics companies
Male tilapia grow faster than females, female trout, salmon and shrimp grow faster than males, and many species develop an off-taste with maturation of either males or females. The production of single sex groups of fish takes advantage of these differences. Administering appropriate hormones can change the phenotypic (i.e. apparent, physical) sex of many aquatic species. For example, genetically male tilapia can be turned into 'physical' females through hormone treatments. These genetic males, that are physically female, are then crossed with normal males to produce a group of all-male tilapia that grow faster.[287] The genetically male tilapia can reproduce with other females but will lose the growth effect. The technology has been developed with public funding from DFID, was then privatized and is now licensed to be sold to farmers in Nigeria, Togo, Benin and Ghana.[288]

The shrimp genetic industry has developed "reproductively sterile, all-female shrimp for commercial culture. As selectively bred shrimp with elite genotypes become available for use to the global shrimp industry, the demand for a genetic protection strategy and method to produce all-female populations has never been so great. Reproductive sterility is of interest as it provides fail-proof genetic protection, whilst all-female populations will substantially improve pond yields when harvested as shrimp females grow larger than males." [289]

Even if monosex populations grow faster, the benefit for farmers is not clear – it depends more on price developments. The genetics companies' benefit is however, guaranteed: "all-female populations at the same time protects the germplasm,"[290] meaning it protects the interest of the breeding company.

Triploidy: Perfect only to protect the genetics company interest
Chromosome-set manipulation is a technique to produce 'triploid' animals that have three (or even four) sets of chromosomes instead of the usual two. Triploids can not reproduce, however, they are not totally sterile. This is not good enough to protect biodiversity from

[285] e.g. F. Piferrer (2007): Use of Triploids to Limit the Genetic Impact of Escapees on Wild Populations – Status and Prospects. The International Symposium on Genetic Impacts from Aquaculture: Meeting the Challenge in Europe. Bergen, Norway 2-4 July 2007
[286] Hans Komen, Henk Bovenhuis and Johan van Arendonk (2006): Consequences of Reproductive Characteristics For Fish Breeding Schemes. 8th World Congress on Genetics Applied to Livestock Production, August 13-18, 2006, Belo Horizonte, MG, Brasil
[287] http://www.fao.org/fishery/topic/14796/en (accessed 7/10/2009)
[288] http://www.fishgen.com/ (accessed 7/10/2009)
[289] Sellars, M. J., Dixon, T. J., Coman, G. J., and Preston, N. P. (2008). Reproductively sterile, all-female shrimp for commercial culture. In: World Aquaculture 2008 - Aquaculture for human wellbeing., Busan, Korea. Korea: World Aquaculture Society.
[290] Hein A. M. van der Steen, John Rocha, Daniel Ciobanu, Alok Deoraj, Donghuo Jiang (2004): Integration of Quantitative and Molecular Genetics – The Way Forward in Shrimp Breeding. Feira Nacional do Camarao – 3rd to 7th of February, 2004, Natal, Brazil

escaped breeds, but enough to make customers return to the breeder for fresh supplies of brood stock instead of hatching the next generation. However, the technology so far seems to only work in trout.

In many aquaculture species, triploidy can be rather easily induced by applying a shock (temperature, pressure or chemicals) to the eggs. The number of species evaluated for triploidy continues to increase, as does understanding of methods and techniques for inducing triploidy, although they often result in reduced performance.[291] Nevertheless, the scientists seem to keep hoping for better results.

According to Compassion in World Farming, triploids are susceptible to a range of health and welfare problems, including higher levels of spinal deformities, eye cataracts, poorer growth and lower survival rates, and triploidy should therefore be prohibited.[292]

Scientists initially thought that without reproduction, the feed energy that was not channeled into reproduction would go instead to increasing growth rate, but this has not worked out. In salmon and trout, triploidy was hoped to prevent degradation of meat quality that is caused by sexual maturation of male fish. It has, however, been shown that sexual maturation is a booster for growth performance several months before sexual maturity becomes a problem. Sterile individuals may consequently grow more slowly towards the end of the production cycle and thus perform poorly.[293]

Trout and oyster are probably the only species where triploid animals are viable. Troutlodge Inc. combines triploidy with all female populations.[294]

No market perspectives are within sight for triploid salmon (which has led to lower growth rates and survival as well as jaw deformities)[295] or triploid carp (it performed lower than the normal diploid carp),[296] two major aquaculture species. In African catfish there are no advantages in performance of triploids over diploids. In other fish species, growth of the triploids is variable, even lower than the diploids.[297] In shrimp, there were biological limitations in obtaining live polyploid embryos that are viable for an extended period.[298] However, some scientists consider the development of triploidy particularly urgent for fish species with short generation intervals, such as the Nile tilapia, Atlantic cod or African catfish.[299]

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[291] Greg Lutz, Advances in triploidy In: Aquaculture Magazine July/August-Products 2007 Issue, pp78-80
[292] Peter Stevenson (2007): Closed Waters: the Welfare of Farmed Atlantic Salmon, Rainbow Trout, Atlantic Cod &Atlantic Halibut. CIWF and WSPA http://www.ciwf.org.uk/includes/documents/cm_docs/2008/c/closed_waters_welfare_of_farmed_atlantic_salmon.pdf (accessed 7/10/2009)
[293] G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway
[294] http://www.troutlodge.com/?pageID=9C4DCE84-3048-7B4D-A93C4B67EECD271F (accessed 7/10/2009)
[295] Ashie Norris, Marine Harvest Ireland (January 2008): Review on Breeding and Reproduction of European aquaculture species: Atlantic salmon (Salmo salar)
[296] Marc Vandeputte, Otomar Linhart, Hans Komen, Gideon Hulata (January 2008): Review on Breeding and Reproduction of European aquaculture species Common carp (Cyprinus Carpio L.)
[297] reviewed by Dunham 2004, and Rasmussen and Morrissey 2007, cited after Henken et al. 1987; Na-Nakorn et al. 2004, cited after Nguyen Hong Nguyen and Raul W. Ponzoni Prospects or Development of a Genetic Improvement Program in African Catfish (Clarias Gariepinus) in: Ponzoni, R.W. and N.H. Nguyen (eds). 2008. Proceedings of a Workshop on the Development of a Genetic Improvement Program for African catfish Clarias gariepinus. WorldFish Center Conference Proceedings Number 1889. The WorldFish Center, Penang, Malaysia
[298] Issues in shrimp triploidy induction Alok Deoraj, Alen Miklica, Anthony Trimboli, Komarey Moss, Lali Abeydeera, M. Andrew Stovall, Dustin Moss, Shaun Moss and Hein van der Steen, Sygen International
[299] Hans Komen, Henk Bovenhuis and Johan van Arendonk (2006): Consequences of Reproductive Characteristics For Fish Breeding Schemes. 8th World Congress on Genetics Applied to Livestock Production, August 13-18, 2006, Belo Horizonte, MG, Brasil

In addition, triploids are more sensitive to sub-optimal rearing conditions, according to aquaculture experts.[300] This would lead to increasing production cost for the control of production conditions like optimum feed, water temperature control and the like. Such requirements also would lead to increased environmental cost, the "externalized cost" paid by citizens of current and future generations. A few years and EU funded aquaculture research programmes earlier, experts had also pointed at the need to investigate sociological, ecological and economical impacts of sterile fish,[301] but this was not developed into a priority of neither private nor public researchers.

Although triploidy is therefore primarily for commercial interest of genetics companies, some public research programmes are supporting its development. For example, the Australian CSIRO have been optimising triploidisation technologies developed in the shrimp variety *Penaeus japonicus* to be suitable for commercial-scale triploidy in the two regionally more important varieties Black tiger prawn *Penaeus monodon* and Pacific White shrimp *Litopennaeus vannamei.*[302] Another example is the grant by the Canadian government to AquaBounty for the development of triploid salmon January 2009.[303]

Tracing and documentation of possible unauthorized use of genetic material
The genetics industry is looking for a possibility to control and document the origin of brood stock. Allele frequencies, marker genes and DNA fingerprinting are gene technology and biochemical methods together with databases that have already been applied for such tracing or pedigree control.
The tracing by DNA fingerprinting could be established nationally or even internationally, by making pedigree certificates mandatory for all hatcheries and grow-out farmers, suggests the Akvaforsk/FNI study.[304]
In livestock, where individual animals may be of high breeding value, pedigrees play an important role but are not linked to DNA fingerprinting.

Mandatory traceability may be a good income source for companies specialised on DNA fingerprinting. Such a regulation would be inappropriate for developing and even industrialised countries:
Artisanal hatcheries and grow out farmers may have no means to use DNA fingerprinting or to establish pedigrees or to issue certificates.
If animals escaped from aquaculture farms contaminate other farms or are caught from the wild, aquaculture farmers of fishers could be fined. In Chile, despite massive escapes from salmon farms and large quantities of salmon in the wild, the law prevents fishers and others without an aquaculture license from catching and selling salmon. Those doing so risk a fine or imprisonment.

Increased inbreeding levels
Shrimp breeders are recommended to sell brood stock that will accumulate ever-increasing levels of inbreeding in successive generations as a biological mechanism for property

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[300] Knowledge gaps and research priorities. Presentation at ReproFish - AquaBreeding Workshop October 2008 – Paris, France, www.aquabreeding.eu (accessed 7/10/2009)
[301] Pierrick Haffray and Anne Marie Neeteson (2002): Breeding and genetics : status, challenges, outlook and sustainability. Presentation in a EU funded project workshop: Sustainable European Farm Animal Breeding And Reproduction (SEFABAR)
[302] Sellars, M. J., Dixon, T. J., Coman, G. J., and Preston, N. P. (2008). Reproductively sterile, all-female shrimp for commercial culture. In: World Aquaculture 2008 - Aquaculture for human wellbeing. Busan, Korea. Korea: World Aquaculture Society.
[303] ACOA News Release 23 January 2009 http://mediaroom.acoa-apeca.gc.ca/e/media/press/press.shtml?4266 (accessed 7/10/2009)
[304] G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway

protection of shrimp breeding stock. “Pirated” shrimps will have a very low reproduction rate or even die.[305]

What about hybridization in aquaculture?
Hybrid production organisation has almost completely taken plant breeding and much of animal breeding out of the hands of farmers in industrial systems. When two different breeds or breeding lines are crossed, productivity of the offspring increases considerably. However, this “heterosis” effect fades away in the following generation. In plant as well as in animal breeding, companies sell only the hybrids and keep the parent lines (usually separate lines with important male and female traits like high milk or egg production, fast muscle growth) inaccessible to their customers. These customers – multipliers and hatcheries in case of pigs and poultry- have to return to the breeding company for every new generation, and so do the farmers return to the multipliers and hatcheries, and seed traders for each new generation.

In aquaculture breeding, applied hybrid programmes are scarce, while hybrid forms of many fish species exist in research programmes.[306] However, cross-breeding experiments with stocks in aquaculture species have until now largely failed to detect major or applicable heterosis effects.[307] Possibly, deliberate inbreeding in the parent lines may increase the heterosis, but this strategy is expected to encounter the same problems with inbreeding problems in the parent lines as in other farm animals. The gain from cross-breeding in aquaculture is typically lower than the gain in selection programs.[308]

Combined strategy: The “Protection Rings”
A former shrimp genetics industry breeder has defined the “Protection Rings:”
“As long as the ultimate protection, i.e. high quality sterile Post larvae (PL)[309], is not in place, the breeding industry will have to rely on ‘rings of protection’ such as:
- Contracts (prevents use of PLs for breeding)
- Traceability (allows tracing shrimp back to previous generation)
- Cross between inbred lines (PLs less suitable for breeding)
- Sell a narrow genetic base (PLs less suitable for breeding) and
- Fast progress.”[310]

The authoring “Lord” of the aquaculture industry protection rings, Hein van der Steen led the world’s largest pig and shrimp genetics company, Sygen, until it spun off with the formation of Genus plc. In 2006, he filed an extremely broad patent on “Animal Breeding System and Method” (WO/2007/135561).[311]

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[305] Roger W. Doyle, Dustin R. Moss, Shawn M. Moss (April/May 2006): Shrimp Copyright: Inbreeding Strategies Effective Against Illegal Copying of Genetically Improved Shrimp http://pdf.gaalliance.org/pdf/gaa-doyle-apr06.pdf (accessed 29 Dec 2006)
[306] G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway
[307] Gjerde and Refstie, 1984; Gjerde, 1988; Gjerde et al., 2002; Bentsen et al., 1997 , cited in G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway
[308] G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway
[309] PL stands for Post Larvae, the technical term for commonly traded young shrimp for outgrowing.
[310] Hein A. M. van der Steen, John Rocha, Daniel Ciobanu, Alok Deoraj, Donghuo Jiang (2004): Integration of Quantitative and Molecular Genetics – The Way Forward in Shrimp Breeding. Feira Nacional do Camarao – 3rd to 7th of February, 2004, Natal, Brazil
[311] http://www.wipo.int/pctdb/en/wo.jsp?WO=2007135561 (accessed 7/10/2009)

8 Intellectual property rights in aquaculture genetic resources

In the previous chapter, technical ways to prevent others from breeding were discussed; now we are turning to the question how the aquaculture genetic scientists are involved in the discussion on reserving private intellectual property rights on genetic resources.

"Rings of protection" work better than patents on animals

"Access or exchange of fish genetic resources and legal protection of investments and research in aquaculture have not been addressed extensively," states a publication on this issue.[312] A reason may be that fewer research institutes are dealing with aquaculture species than with livestock or crop species, but the aquaculture genetics science has grown tremendously over the past decade.
With multiple rings of protection in place, the aquaculture genetics industry is not at the spearhead of those pushing for animal patents. Broad patents may be an argument to attract shareholders. But patents are valid for a limited time of 20 years, costly to defend in case of infringements, and the knowledge is published. Technical ways to prevent others from breeding are more durable, and the knowledge may be kept as trade secret.

In this chapter, the details of patent rights in animal breeding are not described or discussed; an overview is available from the Fridtjof Nansen Institute.[313]

The same Norwegian institute is propagating other instruments to protect intellectual property, animal breeders' rights. It follows the model of plant breeders' rights. Although the objective is intellectual property protection, animal breeders' rights are propagated at FAO's negotiations on Animal Genetic Resources that are aimed at environmental and rural development objectives, like food security and poverty alleviation.

Aquaculture geneticists favour "Animal breeders' rights"

The Norwegian aquaculture research institute Aquaforsk/NOFIMA (the one that gave its salmon breeding families away to AquaGen AS, see Chapter 5) jointly with FNI developed an argumentation line to establish "breeders' rights" in the World Trade Organisation's TRIPS Agreement.[314] Countries that become WTO member have to sooner or later comply with the TRIPS Agreement and e.g., establish specific patent rules.

The argumentation line starts from a comparison with plant breeders' rights in the TRIPS Agreement. The TRIPS Agreement, when it comes to plants, requires a sui generis system. In practice, the relevant sui generis system is UPOV,[315] and UPOV establishes rights of plant breeders to collect license fees from anyone who is using seed which the plant breeder has got approved for marketing, and registered as his variety; UPOV provides general criteria for approval and registration, which are regulated by national authorities.

Variety approval or registration in most countries is a lengthy and costly process, usually excluding those varieties from the market that are bred by smallholders for their specific needs and environments; it is often considered to have contributed considerably to the

[312] Greer, D. and Brian Harvey. 2004. Blue Genes. Sharing and Conserving the World's Aquatic Genetic Resources. Earthscan: London.
[313] Tvedt, Morten Walløe: 'Patent protection in the field of animal breeding'. In: Acta Agriculturae Scandinavica, Section A - Animal Sciences , Vol 57, No 3, 2007, pp. 105-120 http://www.fni.no/doc&pdf/MWT-AASSA-2007.PDF(accessed 7/10/2009)
[314] Trade Related Intellectual Property Rights, http://www.wto.org/english/docs_e/legal_e/27-trips_04c_e.htm#5 (accessed 7/10/2009)
[315] French acronym for International Convention for the Protection of New Varieties of Plants (Union internationale pour la protection des obtentions végétales).

dramatic reduction of agricultural plant biodiversity of the past decades. The UPOV criteria applied to approval include "*distinct, uniform and stable.*" Uniformity, good as it may be for specific customer interests in uniformity, discriminates against the needs of customers interested in biodiversity.

The aquaculture breeder lobbyists argue that their breeds can't be uniform; if they were uniform, they would have inbreeding problems and not perform.[316] Therefore, the argument goes on, a specially adapted type of intellectual property system for the particular needs of aquaculture breeders may be needed, a so-called "sui generis" (of its own kind) system.[317]

The rights to plant genetic resources are, however, regulated in the FAO International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). Here, the objective is food security and poverty alleviation as well as conservation of biological diversity, while the TRIPS Agreement aims at intellectual property protection. FAO is securing traditional farmers' rights to replant, develop, exchange, or sell their own seed.

The inbreeding point is a very good one – it seems a lesson was learned from industrial poultry, pig and cattle breeding where it is now almost impossible to remedy the massive inbreeding problems. But the point is used in the wrong place. Inbreeding is not prevented by an IPR system, but by careful selection programs. It also can't be an argument in favor of a sui generis IPR system.

The Norwegian study also points to another worry, access rights. Under a free access regime, breeding programs may acquire brood stock with a wide range of characteristics, and also with fresh genetics if a brood stock has inbreeding problems. Free access to both wild and improved genetic resources is therefore beneficial to all actors, according to the Norwegian researchers.[318]

From the perspective of breeding companies, as interviewed by FNI and Akvaforsk, the main issue is to find a balance between access to breeding material (both wild and from other companies, domestic as well as international) and establishing property rights to own innovations in fish breeding.[319] "The sector needs a balance between access to breeding material and protection of own innovations in fish breeding – *sui generis*- suggest the Norwegian researchers.[320] The UPOV Convention –the blueprint sui generis legal system under TRIPS Agreement - provides for an exemption for researchers and for other breeders who develop new varieties.

Animal breeders' rights may not promote aquaculture breeding
Animal breeders' rights may run our societies into the same problems as patents and plant variety protection. The innovation-funding function of both patent laws and plant variety protection is questioned not only in the field of plant crops, and not only by farmers'

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316 Rosendal, G. Kristin, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2006): Access to and Legal Protection of Aquaculture Genetic Resources: Norwegian Perspectives. Journal of World Intellectual Property, Vol 9, No 4, 2006, pp. 392-412.
317 G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources .The Fridtjof Nansen Institute, Norway
318 Rosendal, G. Kristin, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2006): Access to and Legal Protection of Aquaculture Genetic Resources: Norwegian Perspectives. Journal of World Intellectual Property, Vol 9, No 4, 2006, pp. 392-412.
319 G. Kristin Rosendal, Ingrid Olesen, Hans B. Bentsen, Morten Walløe Tvedt and Martin Bryde (2005): Strategies and Regulations Pertaining to Access to and Legal Protection of Aquaculture Genetic Resources. The Fridtjof Nansen Institute, Norway
320 Ingrid Olesen, Kristin Rosendal, Morten Walløe Tvedt, Martin Bryde, and Hans B.Bentsen Who shall own the genes of the farmed fish? "Strategies and regulations pertaining to access and legal protection of aquaculture genetic resources"

organisations around the world,[321] but also by researchers, both public and private. Proliferation of patents is related to blocking research activities of other actors, to increased market power, consolidation and market domination of large companies.

The return from legal protection does not encourage breeding on other than the commercially dominant species. Farmers are restricted to buy seed from sources other than the original breeders or their licensees, and that IP-protected seed systems in many countries have more support from government-lead activities than conventional seed systems. Particularly smallholders are affected, as IP protected seed is more expensive.[322] Empirical evidence as reported by a study for the World Bank on five developing countries shows that a thriving plant breeding sector is possible without plant variety protection.[323]

Access rights to wild aquaculture species

The Convention on Biological Diversity (CBD) has since 1992 placed biological diversity (including species as well as their environments, genetic resources and traditional knowledge) under national sovereignty. The CBD objectives regarding food and agriculture are under the responsibility of FAO. Most species, crop varieties and animal breeds exist in more than one country, and therefore international cooperation is essential to attain the CBD objectives of conservation, sustainable use and equitable sharing of benefits with regard to biological diversity. Aquaculture species, moreover, also populate the High Seas outside of the sovereignty of any particular country. Access to marine and freshwater biological diversity (including related traditional knowledge) is therefore de facto often available, but access rights are not always followed up.

Wild aquatic species, as described earlier, are however, very important genetic resources relevant to food supply:[324]

1. Collection of juveniles from the wild for aquaculture purposes is still practiced in a variety of species, and in many countries, both industrialized and developing countries. In some cases, collectors are over-using the resources, in others, the resources are plentiful as long as the environment where they grow, is intact.
2. Inbreeding is a danger that comes along with breeding. A reservoir of wild relatives, that are not frozen in genebanks, but genetically up to date with regard to changing challenges, is essential.

National legislation on collection from the wild needs therefore careful assessments.

In adapting the international legal framework with regard to aquatic genetic resources, FAO's Multi-Year Programme of Work will be essential with regard to the objectives of food security and poverty alleviation. The WTO TRIPS Agreement as well as related solutions that focus on animal breeders' rights may only contribute to the already large control of corporations of the aquatic food resources.

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[321] e.g. http:// www.no-patents-on seeds.org (accessed 7/10/2009)

[322] Geoff Tansey and Tasmin Rajotte (2008): The future control of food. A Guide to International Negotiations and Rules on Intellectual Property, Biodiversity and Food Security

[323] World Bank, cited after Geoff Tansey and Tasmin Rajotte (2008): The future control of food. A Guide to International Negotiations and Rules on Intellectual Property, Biodiversity and Food Security

[324] There are many other functions of wild aquatic species, that have been discussed elsewhere e.g. FAO Commission on Genetic Resources for Food and Agriculture (June 2007): The world's aquatic genetic resources: Status and needs, Rome

9 Conclusions

Aquaculture is a sector where local communities are the predominant actors and are contributing to food security and income. These communities, particularly in China and other Asian countries, have made aquaculture grow by almost 9 percent per year over at least three decades, while agriculture in general grew by just one third of that rate. In recent years, large investments in industrial aquaculture, public subsidies, and new regulations and legislation pertaining to industrial aquaculture have emerged and more are to be expected. Existing land and water resources are being diverted from local artisanal uses (fishing, farming, gathering, etc) to industrial aquaculture. Industrial feed is replacing local feeds. Genetics companies and collaborating research organisations are working on an increasing number of aquatic species, and are developing business strategies to dominate the markets for aquatic seeds.

A number of developments in industrial aquaculture are taking place that need urgent attention. Market domination especially by genetics companies is a clear danger that may develop with industrial aquaculture. Market penetration is remarkably high in livestock. Global market shares of genetics companies reach up to 60 percent. In poultry, the genetics are locked in four global poultry genetics corporations who keep genetic information as trade secrets.

The largest aquaculture genetics company, AquaGen AS, was itself integrated in the world's largest poultry genetics company, EW Group. Market domination in aquaculture genetics, with the experience and financial power of genetics corporations, may be a much faster process than so far seen in livestock or plant genetic companies. ***National and EU competition control agencies should look into possible abuse of market dominating positions.***

It is time to assess the impacts on smallholders of the "livestock revolution" which is often taken as a model for aquaculture. Not only have livestock farmers lost control of breeding, and can no longer define breeding objectives. Many smallholder farmers have become integrated in corporate value chains with standard contracts. Farm investments, especially with regard to "Biosecurity" (to reduce the risk of disease) are high, and so is farmer indebtedness. Such corporate value chains are increasingly established in aquaculture. As in the example of Vietnamese pangasius for export, smallholders are producing close to the break even point. They are economically vulnerable. The production risk in aquaculture being high, particularly due to the danger of fish pests and diseases, indebtedness is a likely consequence. ***Smallholder contract aquaculture needs monitoring with regard to occurrence, negotiating power, indebtedness, production risk and other parameters.***

It is crucial to protect and support small producers given their important contribution to food and livelihood security and to in situ biodiversity conservation (see Chapter 5).

The dimensions of global livestock diseases like Avian Influenza are no surprise to veterinarians given the genetic similarity and the neglect of selection for fitness and resistance over many generations. Increasingly, veterinarians depend on companies, as their service has become part of the contract arrangements of the genetics companies, or their multipliers, with farmers. The risk of serious diseases in industrialised aquaculture is now no longer just a possibility, but a reality. Shrimp farmers in Asia and Latin America had to suffer losses from an almost total collapse due to viruses. Currently, the salmon industry in Chile - set up only a few years ago- has collapsed due to sea lice and ISA virus infestations. The economic scale of these losses are comparable to the "Sunken Billions" of the oversized trawler fleets that deplete the oceans, as recently described by the World Bank. ***The economic implications of diseases associated with industrial aquaculture need further study, particularly with regard to their impact on smallholders.***

A shift from local, home prepared feed resources to industrial **compound feed** is taking place that implies additional loads of carbon emissions contributing to climate change. The fact that fish is a better feed converter than livestock is not cooling but heating the climate if aquaculture growth is built on more polluting feed production processes. The efforts made to reduce the share of fishmeal and fish oil in the increasing amounts of compound feed may only mask the fact that millions of tons of low value fish are each year turned into fish feed, and a reduction of that absolute amount is not within sight. Industrial aquaculture increasingly turns to soya and other environmentally problematic feed resources, and feed mills are mushrooming in many Asian countries. Instead***, local fish feed solutions need to be strengthened.***

What is more, industrial aquaculture has so far in its technology development largely ignored the **environmental services** of smallholder aquaculture. It is estimated that the ecosystem services of aquaculture could be as important as food production: Turning waste to feed, cleaning waste water, and reducing a range of disease vectors from open water bodies. Biological diversity conservation services, live gene banking of hundreds of species and millions of individuals, and their genetic development are all so far hardly discussed services, while destructive collection from the wild dominated the discussion.
A paradigm change of aquaculture development is needed from industrialisation to supporting the existing smallholder-led production growth.
Investments in aquaculture, public subsidies, and new regulations and legislation should follow the smallholder leadership paradigm.

It is crucial to protect and support such small producers given their important contribution to food and livelihood security, and to *in situ* biodiversity conservation (see Chapter 5).

If industrial livestock farmers would like to return to more sustainable production methods, they have a hard time. No breeds of layer hens, broiler and turkey are available any more that would be suitable for organic production; Organic farmers are using the industrial lines. Only very few suitable pig breeds are left. In-breeding in cattle and pigs has reached levels that correspond to the highest risk category known in biological diversity science. Only in Scandinavia, farmers were strongly organised and to some extent prevented the genetic uniformity that is globally pervasive in industrial livestock breeds.
The technologies of industrialised aquaculture so far have followed similar questionable objectives. Among them, genetic selection for fast growth has overridden all other selection goals. ***Public support to industry led research and development must be turned towards smallholder-led breeding and technology development.***

Proprietary strategies are designed to prevent the customers – i.e. fish growers - from using the animals for more than one generation, or from running their own breeding programme on the basis of those animals. In poultry, the genetics are locked in four global poultry genetics corporations as trade secrets. They keep the great-grandparent generation and through contract-tied multipliers and hatcheries, day old chicken are sold: male broiler lines to outgrowers, female layer lines to egg producers. They are not sterile, but reproduction would not be competitive. The chicks for half of the world's eggs and three quarters of its broilers are sold through this proprietary value chain.

In several aquatic species, the sterilization technology, triploidy (animals have triple chromosome set instead of double), is relatively easy to achieve but does not work well. It does not well protect the environment from contamination. Moreover, many species react negatively to triploidy, by not growing well, or by developing defects. Triploidy is however, perfect enough to protect the interest of the genetics company. The technology so far is marketed mainly in trout and oysters; in most other species, the impact on the animals may be too negative to sell them. Companies use other ways to make breeding by customers less attractive, like selling animals of the one sex that grows faster, either female as in trout or salmon, or male as in tilapia. This seems lucrative for both the company and the customer, but possible advantages of customers, like lower production cost, can be easily absorbed by price developments, while the advantage to the company, a dependent customer, remains. Tilapia being a crop promoted for smallholders in many developing countries, ***there is an urgent need to investigate sociological, ecological and economical impacts of triploid aquatic seeds and monosex populations. Public funding to such technologies must be phased out.***

The United Nations are maintaining since 2000 a moratorium on such “Genetic Use Restriction Technologies” (or: Terminator technologies) in plants. Socioeconomic reasons for the ban include rising cost for seed and a total dependency on seed corporations, not only of farmers, but also whole countries. Environmental reasons include the unreliability of the technologies. ***A UN moratorium is due on aquatic genetic use restriction technologies as well.***

Other proprietary strategies include high inbreeding levels, or crosses between inbred lines (so that the next generation is not only more productive but also less suitable to breeding), contracts that exclude customers from breeding, and biotechnological traceability, so that trespasses can be prosecuted. Such proprietary strategies help the genetics corporations secure revenues as well as increase their market shares, for example the multi-species livestock genetic corporations. Specific proprietary strategies could trigger a high interest in aquaculture genetics. It is not only likely that aquaculture genetics will become part of these corporations; the first such case is a reality since 2008.

Intellectual Property Rights (IPRs): In addition to these “rings of protection,” patents on GMO animals are admitted in industrialised countries. Patents on non-GMO animals have also been filed, but the public opinion as well as an increasing number of scientists reject such patents for ethical and social reasons. Scientists and policymakers increasingly recognize the proliferation of patents as hurdles to innovation. Animal geneticists are proposing animal breeders’ rights, in parallel to Plant Variety Protection legislation. Variety approval or registration in most countries is a lengthy and costly process, usually excluding from the market those varieties that are bred by smallholders for their specific needs and environments. Animal breeders’ rights may run our societies into similar problems as patents and plant variety protection. ***Patents and Breeders’ Rights based on Intellectual Property Rights legislation should therefore be rejected for aquatic species as well as for plants and animals in general.***

Aquaculture biotechnology is receiving support, including public funding, as if it were a silver bullet to solve any upcoming problems, especially those magnified by industrialised aquaculture. True solutions to public problems, are however, so far hardly available and time horizons are moving with the funding programmes. The experiences from almost two decades of market approved plant biotechnology lead to the conclusion: ***Phase out public support to aquaculture biotechnology.***

Aquaculture biotechnology is not in its infancy. Genetically modified salmon is waiting for market approval since about a decade, and a list of around three dozen species have been genetically modified. With regard to GMO plants, a comparable number have been developed and are being cultivated. Farmers whose fields were found contaminated, have been sued for misappropriation and not paying royalties. Similar problems may be in line for aquaculture farmers.

Biosafety problems of GMO aquatic species are not at all solved. For GMO plants, the Biosafety Protocol of the United Nations regulates damages arising from international trade.

However, the genetics corporations dominate not only the seed markets but also try to impose a private regulation for such damages. The Compact jointly proposed by six seed giants contains conditions that not only no damage incident may ever meet, but also would negatively affect the support of member countries to the Biosafety Protocol.

In view of lacking implementation of international biosafety regulations for animals, and in view of the new US FDA Animal GMO regulation, it is high time to ***establish an international moratorium on market approvals for and public research funding of GMO aquatic species (including plants), and for GMO animals in general.***

Traceability biotechnology is promoted by geneticists to enforce IPRs, and even proposed to be mandatory. Such technologies are beyond reach of local communities and their independent hatcheries.

Aquatic seed production: While in Latin America and Africa, as well as in industrialized countries, the seed of many species are collected from the wild, in Asian countries, hatcheries are covering most of the needs. ***A large number of independent hatcheries combined with protected areas for wild populations are probably the safest way to avoid genetic losses.***

While the focus was on public hatcheries for a long time, it has shifted from centralized to decentralized seed production, a strategy which offers opportunities for smaller farmers to enter into the fish seed business. Building support services at the local level is crucial in expanding fish seed supply. In Asia, even though seed of major cultivated species are produced in sufficient quantities in hatcheries, poor quality is perceived as a major constraint to expansion of freshwater aquaculture. Several approaches have been adopted by countries and farmers to assure fish seed quality. ***Decentralized independent fish seed production should be supported by appropriate breeding strategies to maintain the genetic quality of broodstock***.