Assessment criteria for Norwegian assistance to aquaculture in developing countries

A draft report to Norad

by

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About this report

After more than 60 years of development assistance in the field of fisheries, it is high time that Norway begins determining how to deal with aquaculture, which within a few years will produce more food fish than the traditional capture fisheries. The Norwegian College of Fishery Science at the University of Tromsø was commissioned to make this report. In the process, we have interviewed more than 20 persons from different parts of the Norwegian aquaculture sector, with a special focus on those who have extensive knowledge about aquaculture in developing countries. We are grateful for the time and patience they showed while offering their experiences and advice. Most of the interviews were conducted by Jens Revold. The report is written by Bjørn Hersoug and Jens Revold, both at NCFS, with generous help from a number of experts from other institutions:

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Aquaculture in general, and especially in the developing world, is an enormous subject. We have therefore only scratched the surface, trying to provide a brief overview of the situation, indicating where Norwegian expertise could make an impact. The report ends with a check-list and recommendations for future action. We hope the report can initiate discussion on how Norwegian expertise can contribute to one of the most rapidly increasing food production systems in the world, with important implications for poverty reduction and food safety. We are not claiming that Norway is the world champion in aquaculture (even if we are the largest salmon producer), however, during the last 40 years, the various participants have gained important experiences that could prove useful for other countries trying to establish aquaculture as a food producing sector.

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Bjørn Hersoug Jens Revold

Photo credit: Rolf Engelsen, Institute of Marine Research.

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List of acronyms

AGC	Akvaforsk Genetic Centre
ASC	Aquaculture Stewardship Council
BAP	Best Aquaculture Practices GAA
BI	Norwegian Business School
CCRF	Code of Conduct for Responsible Fisheries
CDCF	Centre for Development Cooperation in Fisheries
CSO	Civil Society Organization
DIAS	Database on Introductions of Aquatic Species
EIFAC	European Inland Advisory Commission
eNGO	Environmental NGO
FAO	Food and Agriculture Organization, United Nations
FHL	Norwegian Seafood Federation (*Fiskeri- og havbruksnæringens landsforening*)
FOS	The Norwegian Aquaculture Farmers´ Sales Union (*Fiskeoppdretternes salgslag*)
GAA	The Global Aquaculture Alliance
GIFT	Genetically Improved Farmed Tilapia
GlobalGap	Global Good Agricultural Practice
GMO	Genetically Modified Organisms
ICES	International Council for the Exploration of the Sea
ICLARM	International Centre for Living Aquatic Resources Management
IMR	Norwegian Institute of Marine Research
IMTA	Integrated Multi-trophic Aquaculture
ISA	Infectious Salmon Anemia
IUCN	International Union for Conservation of Nature
LDC	Least Developed Countries
LIFDCs	Low Income Food Deficient Countries
MAB	Maximum Allowable Biomass
MFA	Ministry of Foreign Affairs (Norway)
MRAG	Marine Resources Assessment Group
NACA	Network of Aquaculture Centres in Asia-Pacific
NCFS	Norwegian College of Fishery Science
NFF	Federation of Norwegian Fish Farmers (*Norske fiskeoppdretteres forening*)
NFSA	Norwegian Food Safety Authority
NGO	Non-governmental organization
NHO	Confederation of Norwegian Enterprise (*Næringslivets Hovedorganisasjon*)
Nifes	The National Institute of Nutrition and Seafood Research
NIVA	The Norwegian Institute for Water Research
Nofima	Norwegian Food Research Institute
NOMA- FAME	MSc in Fisheries and Aquaculture Management and Economics
Norad	Norwegian Agency for Development Cooperation
NSL	Norwegian Seafood Association (*Norske sjømatbedrifters landsforening*)
NTNU	The Norwegian University of Science and Technology
NUFU	The Norwegian Programme for Development, Research and Education
NVH	Norwegian School of Veterinary Science
Oldepesca	Latin American Organization for Fisheries Development
PO	Producer organization
SEAFDEC	Southeast Asian Fisheries Development Center
Seafood.no	Norwegian Seafood Council
Sintef	The Society for Industrial and Technological Research
UMB	Norwegian University of Life Sciences
UoB	University of Bergen
UoT	University of Tromsø
WTO	World Trade Organization
WWF	World Wildlife Fund for Nature

Executive summary

While the traditional capture fisheries seem to have stagnated around 90 million tons per year, aquaculture is at present the fastest growing food sector in the world. It is estimated that aquaculture will meet more than 50percent of global food fish consumption in 2012. In 2011 the global aquaculture production increased to 63.6 million tons. In the period 1980–2010, the production of food fish from aquaculture increased at an average annual rate of 7.1 percent. Despite long traditions for aquaculture in a number of Asian countries, aquaculture is in a global context a relatively new sector. In 1952, the annual global production was less than 1 million tons. Asia dominates the world's aquaculture production, accounting for 89 percent of the total in 2011 (79 percent in terms of value), of which China was responsible for 61 percent in terms of volume, while 51 percent in terms of value. In spite of rapid growth over the last few years, Africa's total production is only 2.2 percent of the world production. Norway is the world's largest salmon producer, but is still only responsible for 2 percent of the total aquaculture production. It is further worth noticing that freshwater aquaculture contributes 60 percent of the total, brackish water 8 percent and *marine* only 32 percent.

The main stakeholders in the aquaculture industry are investors, public authorities, researchers and civil society organizations. They all have important roles to play, but the key to success is how these four groups interact, constituting an *aquaculture system*. The story of the Norwegian salmon industry demonstrates the close cooperation between farmers, researchers and public authorities, while civil society organizations have acted as critical correctives, forcing more sustainable practices over time. The Norwegian development cannot be copied, but some of the experiences may prove valuable for other countries trying to establish aquaculture as a new industry. This applies in particular to the focus on *fish health*, considered key to successful aquaculture farming.

In any aquaculture project there will be a number of potential critical factors. They can be classified according to interventions in the natural environment and environmental impacts, the use of fish for feed, employment and food security, the introduction of new (alien) species, fish health, the importance of institutional frameworks, and investment climate and corruption. In this report, they are discussed within the framework of *industrial aquaculture*. Norwegian expertise is by and large developed within large-scale farming of trout and salmon. The relatively few companies and researchers having worked outside Norway have also been involved in large-scale farming of marine as well as fresh water fish. Very few have experiences from extensive, small-scale farming at the household or village level. This is an area where Asia has superior and extensive expertise. *This does not imply that Norwegian expertise should be used exclusively for industrial projects.* Part of the Norwegian knowledge is considered *generic*, i.e., it can be used for other fish species in other production systems. Generic knowledge regarding seed production, fish feed, fish diseases, vaccines, etc., may be both relevant and highly beneficial if applied also to small-scale production.

According to the inventory made in this report, Norwegian competence comprises the entire production chain, from selecting the right brood stock to the selling of the final product at an international market, including research, education and training as well. Expertise is found in the commercial companies, in universities and research institutions as well as in public administrations on central, regional and local levels. To what extent this expertise can be mobilized is largely a question of funding. The interest of participating in the development of aquaculture in developing countries is present, although it should be noted that most Norwegian commercial fish farming companies have concentrated on salmon and trout, while the supply industries have been involved in a wider range of aquaculture production systems.

Experiences from 50 years of development assistance in the field of fisheries (mainly traditional capture fisheries, marine and inland) indicate that Norwegian assistance has been *too widely spread* (for the time being involving projects in 18 different countries). The same can easily happen with support to aquaculture, spread to a large number of countries with many small projects, where it is difficult to measure any lasting effects afterwards, and where the building of country-specific competence in Norway is weak. Consequently, we have recommended a set of guidelines (checklist) regarding Norwegian support to aquaculture to be followed in development cooperation projects. If Norway will use the Norwegian competence in aquaculture to a fuller extent in the future, the strategy would have to consider two different options:

1) Strategic projects, limited in scope, mainly in management including laws and regulations, research and education. Focus on the countries where Norway is firmly established as donor, but with opportunities for middle-income countries, where it is evident that smaller projects could help to solve particular bottlenecks. Support to multi-lateral organizations to be channeled principally through FAO. This option would be to continue the present policy, with a gradual expansion into aquaculture, based upon specific requests from various countries, without any clear geographical priorities.

2) A larger regional program; 150-200 million NOK (over four years), preferably based in one or a few Asian countries, open to participants from several countries and encompassing several disciplines. The idea would be to create a program for aquaculture similar to the "Nansen program" in the capture fisheries. Indirectly, such a program would contribute to the reduction of poverty and enhance food security at the same time. The program could be anchored to one (or a few selected) Asian aquaculture institutions, while on the Norwegian side the expertise would be available through a network of Norwegian companies and universities, possibly coordinated by the CDCF at IMR (Bergen). Such a program could be centered on education at various levels, from technical staff all the way to PhDs for special areas of interest for Asian aquaculture. The program would concentrate on training, research and education and continue for a relatively long period of time (10-12 years). At the moment, three specific areas seem to be of great importance, where Norwegian competence could make a contribution, both in inland and marine aquaculture:

- Aquaculture management/legislation
- Research and development
- Education/training

Chapter 1

Overview of aquaculture

1.1 Global aquaculture production

In the following, we are presenting a number of facts and figures to illustrate the increasing significance of aquaculture production, based on FAO's (2012) assessment of State of World Fisheries and Aquaculture, largely based upon production figures from 2010. First, aquaculture plays an increasing role in terms of the global fish production. Global aquaculture production (excluding plants) increased from 32.4 million tons in 2000 to 63.6 million tons in 2011, while the contribution of aquaculture to global *food fish consumption* rose from 33.8 percent to 48.6 percent in the same period. It is estimated that aquaculture will meet more than 50 percent of global food fish consumption by 2012. In the period 1980–2010, the production of food fish from aquaculture increased at an average annual rate of 7.1 percent, while the world population grew at an average of 1.5 percent per year. The combined result of development in aquaculture worldwide and the expansion in global population is that the average annual per capita supply of food fish from aquaculture for human consumption has increased by seven times, from 1.1 kg in 1980 to 8.7 kg in 2010.

Despite long traditions for aquaculture in a number of Asian countries, aquaculture is in a global context a relatively new sector. Hence, in 1952, the annual production was less than 1 million tons, while it had increased to 63.6 million tons in 2011, increasing more than three times faster than the world's meat production. Table 1 shows the development of aquaculture per region. Here it is worth noting that Asia is dominating the world's aquaculture production. Asia accounted for 89 percent of the world aquaculture production in 2011 (78.7 percent in terms of value). China alone accounted for 61.4 percent in terms of volume, while 51.4 percent in terms of value. However, the figures from China should be treated with some caution, as should production figures from other countries with less reliable systems of production statistics.

Even if Africa as a region has shown a rapid growth over the last years, its total production is only 2.2 percent of the world production, and that figure can further be placed in context, by noting that the total production of aquaculture fish from all African countries is still not more than the 2012 annual production of salmon and trout in Norway (approximately 1.3 million tons). From table 2 we can see that of the top ten aquaculture producers, nine belong to developing countries, led by China and India, with Vietnam and Indonesia coming next. Norway is actually the only exception. Among the least developed countries (LDCs), we find only two countries among the top ten producers, namely Bangladesh and Myanmar. Altogether the LDCs account for only 4 percent of the aquaculture production in the world.

Table 1.1: Aquaculture production by region: quantity and percentage of world production

Selected groups and countries		1970	1980	1990	2000	2009	2010
Africa	**(tonnes)**	**10 271**	**26 202**	**81 015**	**399 676**	**991 183**	**1 288 320**
	(percentage)	***0.40***	***0.60***	***0.60***	***1.20***	***1.80***	***2.20***
Sub-Saharan Africa	(tonnes)	4 243	7 048	17 184	55 690	276 906	359 790
	(percentage)	*0.20*	*0.10*	*0.10*	*0.20*	*0.50*	*0.60*
North Africa	(tonnes)	6 028	19 154	63 831	343 986	714 277	928 530
	(percentage)	*0.20*	*0.40*	*0.50*	*1.10*	*1.30*	*1.60*
Americas	**(tonnes)**	**173 491**	**198 850**	**548 479**	**1 423 433**	**2 512 829**	**2 576 428**
	(percentage)	***6.80***	***4.20***	***4.20***	***4.40***	***4.50***	***4.30***
Caribbean	(tonnes)	350	2 329	12 169	39 704	42 514	36 871
	(percentage)	*0.00*	*0.00*	*0.10*	*0.10*	*0.10*	*0.10*
Latin America	(tonnes)	869	24 590	179 367	799 234	1 835 888	1 883 134
	(percentage)	*0.00*	*0.50*	*1.40*	*2.50*	*3.30*	*3.10*
North America	(tonnes)	172 272	171 931	356 943	584 495	634 427	656 423
	(percentage)	*6.70*	*3.70*	*2.70*	*1.80*	*1.10*	*1.10*
Asia	**(tonnes)**	**1 799 101**	**3 552 382**	**10 801 356**	**28 422 189**	**49 538 019**	**53 301 157**
	(percentage)	***70.10***	***75.50***	***82.60***	***87.70***	***88.90***	***89.00***
Asia (excluding China and Near East)	(tonnes)	1 034 703	2 222 670	4 278 355	6 843 429	14 522 862	16 288 881
	(percentage)	*40.30*	*47.20*	*32.70*	*21.10*	*26.10*	*27.20*
China	(tonnes)	764 380	1 316 278	6 482 402	21 522 095	34 779 870	36 734 215
	(percentage)	*29.80*	*28.00*	*49.60*	*66.40*	*62.40*	*61.40*
Near East	(tonnes)	18	13 434	40 599	56 665	235 286	278 061
	(percentage)	*0.00*	*0.30*	*0.30*	*0.20*	*0.40*	*0.50*
Europe	**(tonnes)**	**575 598**	**916 183**	**1 601 524**	**2 050 958**	**2 499 042**	**2 523 179**
	(percentage)	***22.40***	***19.50***	***12.20***	***6.30***	***4.50***	***4.20***
European Union (27)	(tonnes)	471 282	720 215	1 033 982	1 395 669	1 275 833	1 261 592
	(percentage)	*18.40*	*15.30*	*7.90*	*4.30*	*2.30*	*2.10*
Non-European-Union countries	(tonnes)	26 616	38 594	567 667	657 167	1 226 625	1 265 703
	(percentage)	*1.00*	*0.80*	*4.30*	*2.00*	*2.20*	*2.10*
Oceania	**(tonnes)**	**8 421**	**12 224**	**42 005**	**121 482**	**173 283**	**183 516**
	(percentage)	***0.30***	***0.30***	***0.30***	***0.40***	***0.30***	***0.30***
World	**(tonnes)**	**2 566 882**	**4 705 841**	**13 074 379**	**32 417 738**	**55 714 357**	**59 872 600**

Notes: Data exclude aquatic plants and non-food products. Data for 2010 for some countries are provisional and subject to revisions. Production values for 1980 for Europe include the former Soviet Union.

Source: FAO 2012: 27.

It is further worth noting that freshwater aquaculture contributes 60 percent of the total (measured in volume), brackish water 8 percent and marine aquaculture the remaining 32 percent. The freshwater production is dominated by carps and tilapias, while aquaculture in marine waters is dominated by molluscs (76 percent), finfish (19 percent), and crustaceans (4 percent). The number of species recorded in FAO's aquaculture statistics increased to 541 species and species groups in 2010, including 327 finfishes, 102 mollusks and 62 crustaceans. In a Norwegian context, where Norway figures as the world's largest salmon producer, it should be noted that the production of salmon still represents only 2 percent of the total aquaculture production. Hence, within salmon production, Norway is important, but globally Norway is a minor player in terms of production volume from aquaculture.

Table 1.2: Top ten aquaculture producers according to production in 2010

World	Tonnes	Percentage
China	36 734 215	61.35
India	4 648 851	7.76
Viet Nam	2 671 800	4.46
Indonesia	2 304 828	3.85
Bangladesh	1 308 515	2.19
Thailand	1 286 122	2.15
Norway	1 008 010	1.68
Egypt	919 585	1.54
Myanmar	850 697	1.42
Philippines	744 695	1.24
Other	7 395 281	12.35
Total	**59 872 600**	**100**

Source: Source: FAO (2012: 28).

In terms of employment, the aquaculture sector is estimated to employ around 16.6 million people, or 30 percent of the total engaged in the fisheries and aquaculture sector. Together with additional industries and dependents, aquaculture is now estimated to cater to approximately 100 million people. The distribution is, however, extremely uneven, with 97 percent of the fish farmers found in Asia, and only 150,000 in Africa, including part time fish farmers. While the number of traditional catch fishermen has decreased over the last few years, the number of aquaculture farmers has increased by 5.5 percent per annum.

Table 1.3 Fish farmers by region (in 1000)

Africa	2	61	84	124	150
Asia	3 772	7 050	10 036	12 228	16 078
Europe	32	57	84	83	85
Latin America and the Caribbean	69	90	191	218	248
North America	...	...	...	4	4
Oceania	2	4	5	5	6
World	**3 877**	**7 261**	**10 400**	**12 661**	**16 570**

Source: FAO (2012: 41).

Around 40 percent of the total fish production (capture and aquaculture) enters the world market, which means that a considerable part of aquaculture fish for food consumption is traded. The importance of fish as an export commodity can be seen from figure 1.1. Here it is shown that fish products makes up more than the combined export income of traditional export products such as coffee, cocoa, bananas and rubber.

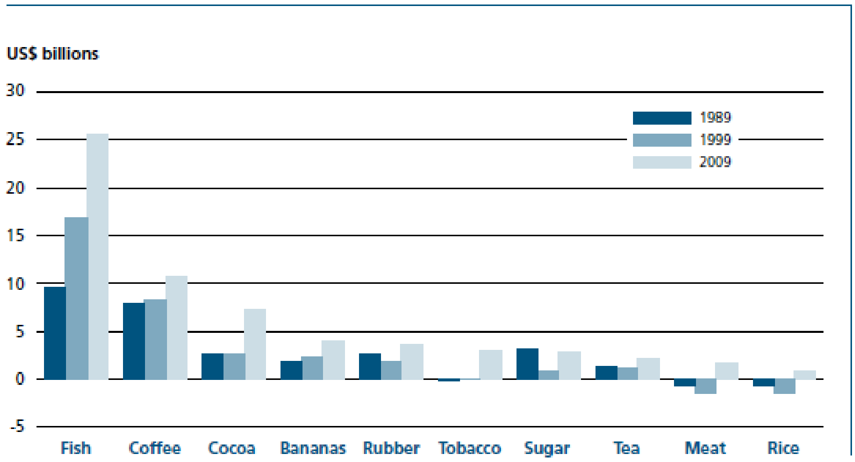

Figure 1.1 Net export by value of selected agricultural commodities by developing countries
Source: FAO (2012: 72).

The aquaculture sector has further expanded, intensified and diversified in the past decade. The expansion has primarily been due to research and development breakthroughs, compliance with consumer demands and improvements in aquaculture policy and governance. Many countries have followed an aggressive policy trying to increase the supply of seafood, either for export or for home consumption, or both. These countries have established regulatory regimes that support industry expansion and growth, while the question of sustainability has not been afforded the same attention. However, many countries have tried to apply the principles of an ecosystem approach to management in accordance with the Code of Conduct for Responsible Fisheries (CCRF).

According to FAO (2012), the environmental performance of the aquaculture sector has continued to improve as a result of a combination of appropriate legislation and governance, technological innovations, risk reduction and better management practices. In many countries, sea-farming activities have expanded, as has promotion of multi-trophic aquaculture, causing reduced environmental impact. Aquaculture networking has improved, and communication between different stakeholder groups has been increased. Aquaculture technology has also been improved, and several new species have emerged (such as striped catfish, tuna, and cod). Some have also reached production volumes sufficient for stable markets to develop, but often the cultured fish species have not been able to attract higher prices than the wild capture fish (as has been the case with farmed cod in Norway).

The quantity and quality of seed and feed have increased globally as producers have responded both to consumers' concerns and to the availability of resources. Significant improvements in feed conversion rates have been recorded, and the reliance on fishmeal and fish oil has been reduced for several species (see chapter 3). In general, aquaculture health management and biosecurity have improved, although sporadic outbreaks of transboundary diseases have occurred in most regions. The use of veterinary drugs and antimicrobials has come under increased scrutiny, and legal frameworks for controlling their use have been established in many countries. However, effective enforcement of such laws is still constrained by a shortage of financial and human resources.

1.2 Large differences in terms of regional development

In the past decade, the Asia-Pacific region has witnessed the highest overall growth and development of aquaculture. The small-scale farming sector in Asia has managed to comply with consumer demands in importing countries. The use of a cluster management approach to farming and adoption of better management practices have been evident in many countries. This has meant improved food quality and safety for small-scale farmers' aquaculture products and improved access to markets. However, many countries still do not benefit fully from the opportunities offered by international trade, as their aquaculture products have difficulty satisfying the import requirements of some of the leading markets.

In the Asia-Pacific region, we have seen two interesting developments over the last decade. Within ten years, an almost complete shift has occurred in the shrimp production, away from the indigenous black tiger shrimp (*Penaeus monodon*) to the exotic white leg shrimp (*Penaeus vannamei*). There has also been an explosive growth in striped catfish (*Pangasius*) farming in Vietnam, where production reached one million ton in 2009. Despite major technical developments in the aquaculture sector, small-scale producers are still the backbone of the sector and contribute the bulk of the production (FAO 2011).

In Latin America, aquaculture has also developed quickly. The leading producers, Brazil, Mexico, Ecuador and Chile, have led the development, concentrating on species such as salmon, trout, tilapia, shrimp and mollusks. Commercial and industrial-scale aquaculture still dominates in Latin America. There is, however, ample potential for small-scale aquaculture development. Initiatives to develop such aquaculture are under way in the Amazon Basin, one of the largest aquatic environments in the world, having significant aquaculture potential. However, aquaculture in Latin America has also encountered serious problems. In Chile, the outbreak of infectious salmon anemia (ISA) reduced the salmon production to one fourth within two years (2008-2010), putting nearly 25,000 people out of work in the salmon districts in southern Chile.

In Africa, aquaculture production increased rapidly over the last ten years, although starting from a very low base. This growth was due to increasing prices for aquatic products, along with the emergence and spread of small and medium enterprises. The expansion of cage culture, headed by large commercial companies, has contributed to the production of high-value species, primarily intended for overseas markets. Egypt is still by far the most important aquaculture producer in Africa. Several countries in sub-Saharan Africa, including Angola, Ghana, Mozambique, Nigeria, Uganda and United Republic of Tanzania, have also experienced growth in aquaculture. In other countries in sub-Saharan Africa, growth has been slow, largely related to a lack of required inputs (seed and feed) and markets. FAO (2010) claims that African governments have demonstrated increasing support for aquaculture, anticipating benefits to economic growth, food supply and food security as well as for poverty alleviation. However, other experts are more pessimistic about the African outlook, largely because they lack a reliable framework for industrial aquaculture, and because corruption continues to play an important role, thus increasing the economic risk of any aquaculture venture.

The relative importance of aquaculture in global fish production can be seen from table 1.4. For the top three species groups, their shares are already approximately 50percent or higher and the aquaculture sector is steadily growing, especially regarding catfish and tilapias.

Table 1.4: *The relative importance of aquaculture in global fish production per species group*

	Capture production (Mt)		Aquaculture production (Mt)		Proportion of total production from Aquaculture (%)		
Species Group	**2003**	**2008**	**2003**	**2008**	**2003**	**2008**	**Difference**
Carps	2.02	2.21	15.04	19.72	88.2	89.9	1.8
Catfish	2.33	2.77	1.03	2.78	30.8	50.1	19.3
Tilapias	3.95	3.14	1.59	2.80	28.6	47.1	18.4
Eels	0.65	0.62	0.32	0.48	32.9	43.4	10.5
Salmonids	1.16	0.84	1.85	2.26	61.5	72.8	11.3
Other Finfish	50.81	51.79	4.40	5.79	8.0	10.0	2.1
Bivalves	18.43	19.72	11.06	12.65	37.5	39.1	1.6
Gastropods	0.30	0.32	0.21	0.37	41.4	53.7	12.3
Crabs and Lobsters	0.93	0.78	0.49	0.76	34.4	49.4	15.0
Shrimps and Prawns	8.85	8.47	2.59	4.35	22.7	33.9	11.3
Other Invertebrates	1.14	1.18	0.12	0.31	9.7	20.5	10.8
Seaweeds	0.34	0.07	9.02	13.24	96.3	99.5	3.1
TOTAL	**91.31**	**92.3**	**47.9**	**65.81**	**34.4**	**41.6**	**7.2**

Source: Hall et al. 2011

For all important species the relative share of farmed fish is increasing, from 34.4 percent in 2003 to 41.6 percent in 2008. From figure 1.2 we also see that the group consisting of freshwater fishes is the group that is increasing most rapidly. As per 2008 marine fishes represented only 3 percent of the total production (7 percent in terms of value), while diadromous fishes (such as salmon and trout) contributed 6 percent (or 13 percent in terms of value) (FAO 2011: 6).

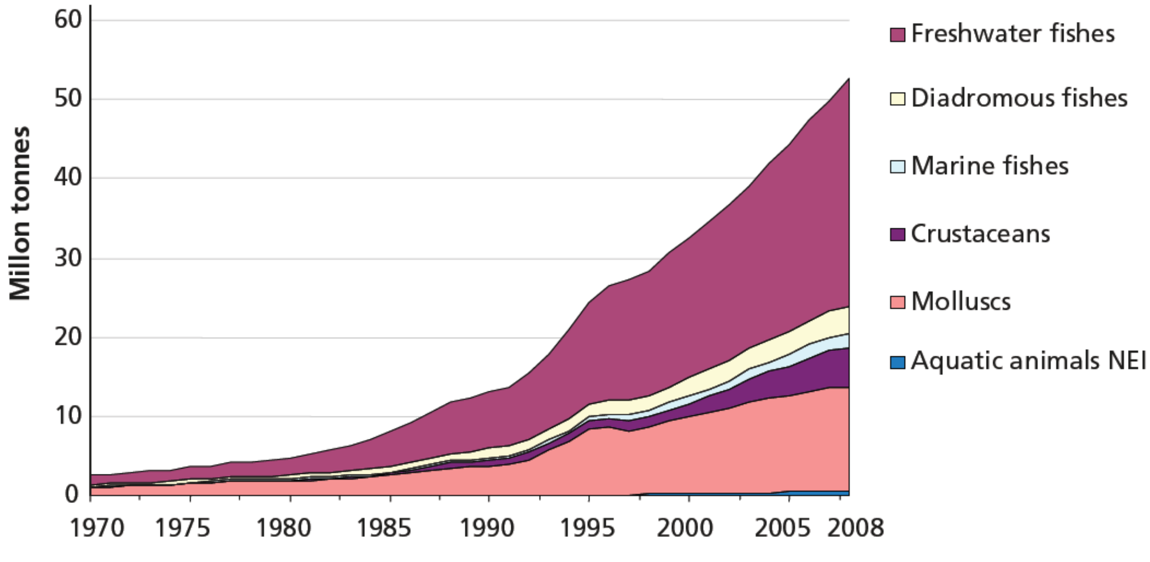

Figure 1.2: Trends in world aquaculture production: major species groups, 1970-2008

Source: FAO (2011: 9).

As previously noted, almost 40 percent (live weight equivalent) of the total annual production of fish has entered international trade in the last decade. Farmed shrimp, salmon, trout, tilapia, catfish and bivalves have contributed significantly to this trade. This increase in trade in aquaculture produce has been accompanied by increased concern in the public and private sectors about:

- environmental impacts of aquaculture;
- consumer protection and food safety requirements;
- animal health and animal welfare;
- social responsibility; and
- traceability and consumer information along the aquaculture supply chain (FAO 2012).

Non-governmental organizations have initiated or strengthened these concerns and developed strategies to exert influence over consumers' purchasing decisions and especially over the procurement policies of major buyers and retailers of fish. These developments have resulted in the proliferation of aquaculture standards and certification schemes designed to trace the origin of fish, its quality and safety, and the environmental and/or social conditions prevailing during aquaculture production, processing and distribution of fish and feed.[1]

[1] Among these we can list the following: GlobalGap, ISO 14001 and 9001, PGI (Protected Geographical Indication), GAA BAP and Aquaculture Stewardship Council (ASC). In addition, we find a number of labels addressing specifically salmon production in Scotland, Norway, Canada and Chile.

1.3 Aquaculture and poverty alleviation

It is difficult to assess the precise influence of aquaculture regarding its contribution to poverty alleviation and food security. According to FAO (2010), it has increased over the last decade. The growing contribution has been caused by larger volumes and increased value of production, thus securing larger employment both in actual farming, processing and in related industries. However, only more detailed studies can tell more precisely who is benefitting from aquaculture production in a specific country. In Vietnam, aquaculture has played an important role in poverty alleviation policies (Béné et al. 2010). From regional statistics, it appears that poverty in general has been reduced from 58 percent of the population in 1993 to only 16 percent in 2004, with improvements particularly in the coastal regions (ref.) Vietnam is also the country where aquaculture is making its largest contribution to the GDP; 16 percent in 2006, followed by Myanmar (8.8 percent) and Lao People's Republic (4.4 percent) (FAO 2001: 65).

Unlike many other sectors of the economy worldwide, aquaculture has generally been resilient in the face of the various economic crises of the last decade. People in the affluent countries have continued to ask for fish, shrimps and crustaceans, while increased availability of low cost fish has also improved the situation in many poorer countries. Still, it is well worth considering that lack of food (including fish) is not the primary problem, even in the poorest countries, but *lack of buying power*. As pointed out by Sen (1981), even hunger crises may not be due to lack of food items as such, but the simple fact that the poor do not have the means to acquire this food. Average fish consumption that plays an important role in FAO's biannual statistics should hence be treated with extreme caution. The availability is a theoretical entity, dividing the fish (from capture fisheries and aquaculture, minus export plus import) with the current population. In countries with large income disparities, this means that the well-to-do classes may have ample fish supplies, while the poorer segments may have considerably less. In any case, a prolonged global economic crisis could severely damage growth in the aquaculture sector by reducing (foreign) investments. Furthermore, reduced state budgets would most likely limit funds available for research and support to vulnerable groups, such as small-scale fish farmers. The use of *conditionalities*, with banks demanding reduced public spending (in order to reduce budget deficits), could further limit funds available for developing the aquaculture industry in many developing countries.

According to FAO (2010), the global aquaculture sector's long-term ability to achieve economic, social and environmental sustainability "depends primarily on continued commitment by governments to provide and support a good governance framework for the sector." In chapters 2 and 3, we have also stressed the value of a good framework for the aquaculture sector, and the possible Norwegian contribution to such a framework. However, it should not be forgotten that aquaculture is most often a small sector, managed under the auspices of a Ministry with many other responsibilities (capture fisheries, agriculture, the environment, or economic development). Previous attempts of creating special conditions for the employees in a specific sector ("sector islands") have not been very successful. Aquaculture management is largely dependent upon the quality of *the entire government apparatus*. This does not imply that assistance to aquaculture has to include the entire government bureaucracy, only that good governance in aquaculture is subject to certain limitations. If the overall state bureaucracy is corrupt, favoring certain economic or ethnic groups and lacks transparency, it is difficult to establish and maintain a transparent, impartial, uncorrupt aquaculture or fisheries administration.

FAO (2010) also warns that the valuable work many governments are doing, trying to protect the environment, but in the process greatly affecting the small-scale farmers by framing legislation that is costly, time-consuming and difficult to implement. Sustainable aquaculture operations are part of a long-term goal, and in the meantime, it is of great importance not to exclude small-scale farmers with few or no other alternative employment possibilities. Bringing aquaculture into a sustainable modus will require committed efforts over a long period. It is well worth remembering that also in Norway it took at least 40 years to bring the industry into a position that may be considered reasonably sustainable – still with considerable problems regarding escapes and sea lice.

FAO (2011: 67) notes that in terms of poverty alleviation and securing food security, the interventions that have proved to be most successful are characterized by: "ownership by the beneficiaries; the use of participatory approaches; being small-scale in terms of investment; being demand-led, with farmers first; use of people-centered approaches; the growing of species that feed low on the food chain (e.g. carp, catfish and tilapia); the targeting of all household members; and the use of farmer-field-school-type methodologies and of technologies that are developed according to the local context with network approaches." These lessons provide a special challenge to Norwegian expertise, largely developed through more industrial projects, based upon species that feed high in the food chain, and with relatively little experience in extension models based upon farmer-field-school methodologies.

1.4 Future trends and environmental impacts

The WorldFish Center in Malaysia has recently tried to forecast future trends of aquaculture production, under different assumptions. From figure 1.3 below, we see that the different projections vary substantially. Much depends upon the development of the traditional capture fisheries (which also provide input for feed in the aquaculture industry), the technological development and not least the average consumption of fish per capita.

With a very modest growth of the traditional capture fisheries (0.7 percent per annum) the production level for *aquaculture* in year 2030 is estimated to be around 100 million tons, or a 60 percent increase compared to the present production level. If the distribution is considered to be more or less like today (somewhat less in China, somewhat more in Africa), the environmental impacts will be as indicated in figure 1.4.

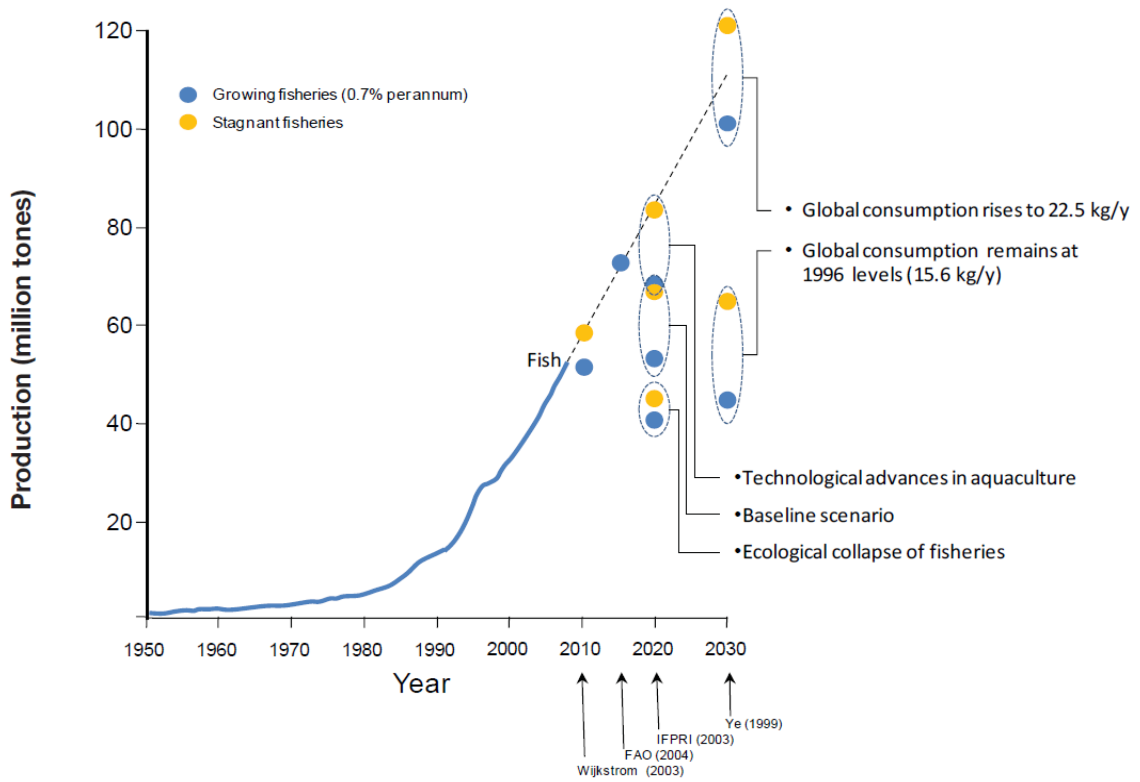

Figure 1.2: Comparison of historical trends in production of farmed fish with several projections of future aquaculture production under various assumptions
(Source: Hall et al. 2011).

Here Hall et al. (2011) have projected the distribution of environmental impacts based upon six different indicators: eutrophication, acidification, climate change, land occupation, energy demand and biotic depletion. *Under this scenario, the environmental demands will be between 2 and 2.5 times greater than the 2008 levels by 2030 for all impacted categories indicated above.* As pointed out by the authors, both the present situation (based upon production in 2008) and the projected production (as per 2030) affirms the importance of focusing support to *Asian* producers, if we are going to mitigate the more dramatic impacts of aquaculture (Hall et al. 2011: 66). Centuries of experience with (inland) aquaculture, as in many Asian countries, is no guarantee for sustainable resource utilization in the future.

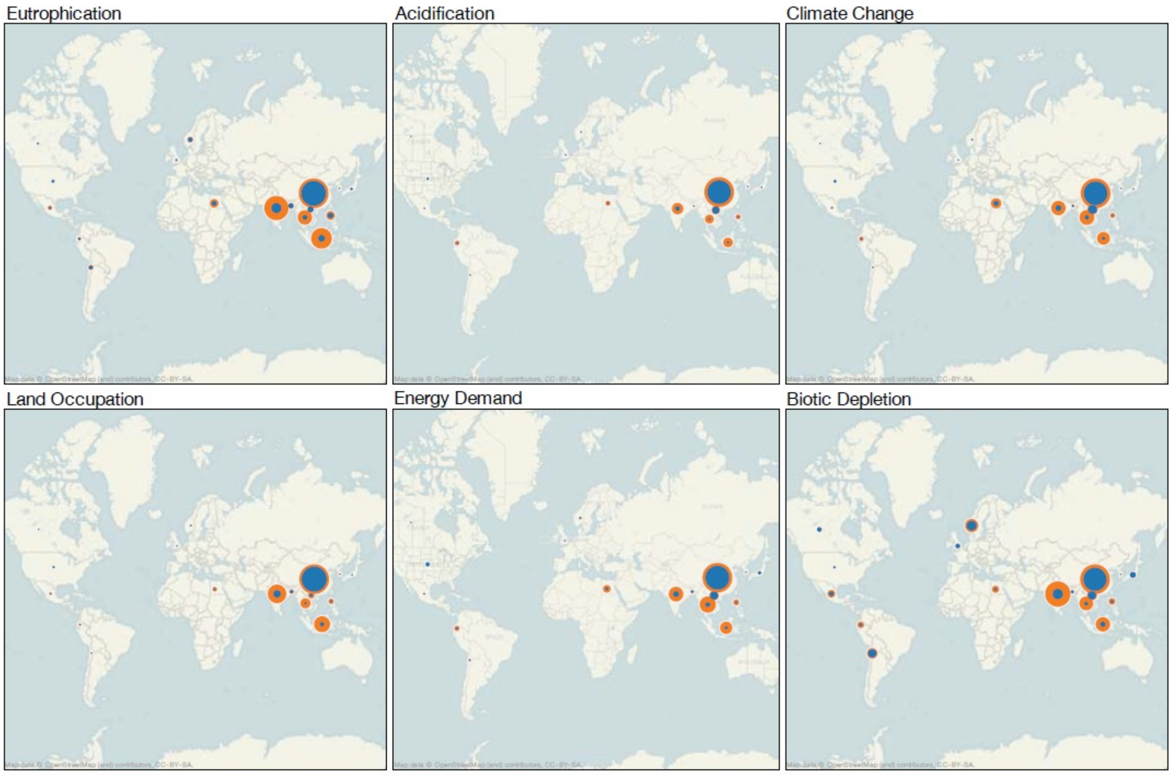

Figure 1.3: Projected changes in distribution of environmental impact categories in 2008 and 2030. Blue circles: 2008 production; orange circles: 2030 production
(Source: Hall et al. 2011).

The importance of aquaculture can be summarized briefly:

- In 2012, aquaculture will produce as much fish for food as the traditional capture fisheries.
- 89 percent of the global aquaculture production takes place in Asia, with China alone being responsible for 61 percent (measured in volume).
- 68 percent of the global aquaculture production takes place in freshwater and brackish water.
- Given that the traditional capture fisheries have stagnated at around 90 million tons per year, maintaining (or increasing) the fish consumption per capita will depend entirely upon increased aquaculture production.
- The largest potential is still in Asian countries, but environmental effects of future expansion are also considered to be most serious in this region.
- Africa is a very minor aquaculture producer, but with a rapid increase over the last ten years. In Latin America, several countries are firmly established within aquaculture, with the largest potential most likely in the Amazon basin (primarily Brazil).
- Increased aquaculture production will largely depend upon private investments, while government authorities have a major role framing rules and regulations.

Chapter 2

Roles and importance of the different actors within the aquaculture sector

This chapter addresses the primary stakeholders on a generic level, that is, without going into details regarding a particular country, fish or management model. In the second part, we provide a short presentation of the Norwegian aquaculture development, with special emphasis on how the different stakeholder groups have cooperated in order to create a highly successful *aquaculture system*, related to the farming of salmon and trout.

2.1 The main stakeholders

Starting with the *management authorities*, they obviously play an important role, setting up the framework within which the aquaculture projects have to be implemented. While both the quality and ability of management authorities may vary considerably from one country to another, there is a prevailing trend that many developing countries search for support in setting up adequate aquaculture regimes. While legislation may vary according to specific historical traditions, type of fish to be cultured, etc., there is nevertheless a trend towards more standardized rules and regulations. This is largely due to the homogenization effects of trade regulations, specifying how products should be produced and processed, not least dealing with health and hygiene. This means that countries that desire to export their products to advanced markets, such as the EU, USA and Japan, will have to regulate their aquaculture industries according to strict standards, often controlled by inspectors from the importing countries. Other countries may try to follow standards prescribed in international conventions and soft law, in terms of guidelines and best practices. A third force to be concerned with is the use of certifying labels, similar to what we find in the traditional catch fisheries. Most often, disease problems or health hazards will force lenient management authorities to introduce stronger rules and regulations. Especially after dramatic declines, produced by too rapid expansion, such as in the shrimp production, management authorities will have to introduce much stricter regulations, thus forcing new practices and quite often a reorganization of the entire industry.

We should, however, note that there is an important difference between having strict rules and regulations *on paper* and *enforcing* those same regulations. The ILA crisis in Chile in 2008-2010 can clearly be seen as the result not only of a liberal regulatory regime, but also of missing implementation of the actual regulations.[2] The fisheries and aquaculture authorities

[2] In 2007, the first outbreak of infectious salmon anemia (ILA) occurred in southern Chile, which during the next two years spread to most of the fish farms in Region X and XI containing most of the farms in Chile. The production of Atlantic salmon was reduced to one quarter, thus creating massive unemployment in the regions most affected. In 2013, it is estimated that Chile will be back to the same production level as before the crisis.

did not have the capacity and competence to carry out the controls specified in the laws and regulations. Quite often, we find that the regulatory regimes may include three different levels (national, regional and local). While national sector management authorities may have sufficient quality and competence, regulatory authorities on lower levels may lack both the qualifications and the resources required to perform an effective control. This applies to means of transportation, such as cars, motor bikes, and boats, as well as maps, GPS and means of checking the conditions under water. Finally, we also find that leading politicians do not necessarily listen to their scientific staff or regulatory agencies. While it is clearly an ideal that policy should be based upon scientific knowledge, the willingness to follow such advice may be lacking, especially when the scientists go against lucrative arrangements involving large investments.

Effective enforcement is costly, and in developing countries, it will always be debatable how much should be paid by the state and how much by the private sector. Certification schemes are most often paid by the private sector, while inspection services and the entire legal system is part of public responsibilities.

It seems to be a general perception that economic development takes place through private investments and the creation of new employment possibilities, and that development assistance at best can make a marginal contribution. Successful development in Asia (India, China, Indonesia, Vietnam, South Korea, Thailand and Malaysia) has been driven by private and state investment in processing industries and services, while development assistance has played a minor role. In Africa (south of the Sahara), development assistance has played a larger role, not least in poor countries such as Tanzania, Mozambique, Zambia, Zimbabwe, Namibia, and Uganda. Within industrial aquaculture, private investors play a crucial role in most projects. For obvious reasons private investors have a profit motive for engaging in aquaculture projects in developing countries. Aquaculture has proved to be a growth sector, with substantial pay-offs to the investors. This does not create problems as long as the rules of the game are fair and transparent. What may create problems are investors with extremely short time perspectives, leaving the projects after a few years, quite often with substantial losses for banks and state authorities involved.

As can be gained from the interviews with various Norwegian business leaders within aquaculture, there are many possible business models. Some prefer to establish a joint venture company, where Norwegian investors go together with local entrepreneurs, setting up new aquaculture operations. On other occasions Norwegian investors establish new companies entirely on their own, bringing in both the capital and the expertise. A more common approach in aquaculture operations has been to buy established (local) companies and merge them into a holding company, acting as the mother company. The advantage of this alternative is that the local company already exists and has proved viable in technical and economic terms. On rare occasions where aquaculture companies already are on the stock exchange, organized take-overs may be simpler, but again depending upon the business atmosphere, where foreign investments may be seen either as a threat or as a welcome opportunity for further development. Norwegian-based companies have utilized all different forms of establishment models in the past, with varying degrees of success. While establishment of salmon operations in Chile may have yielded profits immediately, experiences from Malaysia, the Philippines and Vietnam seem to indicate that companies must have a long-term perspective, where profits can only be achieved in the long run, that is, after 8-10 years.

Large-scale industrial aquaculture is largely knowledge-based and research driven. This applies to the entire range of inputs, from selecting the right brood stock, the most efficient production of fingerlings, the use of appropriate feed, the technological solutions used for the grow out farms, as well as the handling and further processing of the fish. Also within small-scale aquaculture research can play a central role, for example within fish feed, fish health and improved pond management. Improving the rate of survival for fish in extensive aquaculture could vastly improve the economic results for the farmers involved.

Dealing with the *research community* as one entity is difficult. The capacity and quality of the local research community may vary considerably. While in a country such as Vietnam, there are a number of state-owned research facilities, with good expertise in many scientific fields, other countries have just the bare necessities. Vietnam has several universities actively involved in aquaculture research, and produces their own candidates, whereas other countries rely primarily on candidates and expertise educated abroad. The Norwegian expertise is addressed in chapter 4, but suffices to say that the quality of the research community in any country relies to a large extent on the quality of the *network* they are able to establish. Finally, it is a special challenge to retain candidates educated abroad and in the country in the fisheries and aquaculture sector. As evidenced in many countries, such candidates are highly valued in other sectors and may easily be attracted by higher salaries and fringe benefits. Various types of binding agreements can to some extent offset this exodus from the fisheries and aquaculture sector.[3]

Regarding civil society, the stakeholders most affected by an aquaculture project are seldom organized. Civil society organizations (CSOs) may play an important role in framing where and how aquaculture farming can operate. However, civil society is often represented by non-governmental organizations and in particular by environmental NGOs. Some of these are committed to challenging any type of industrial aquaculture, while others, such as World Wildlife Fund for Nature (WWF), have entered into a dialogue with the large scale producers in order to create production standards (see, e.g., the establishment of ASC certification for *Pangasius* in Vietnam and the Salmon Dialogue establishing a standard for salmon production worldwide[4]). There is no doubt that civil society organizations may, and should play an important part in framing the conditions for aquaculture operations, small or large. Especially in countries where political parties are considered outside the reach of ordinary people, CSOs may take the role of defending the public good, whether this refers to access to resources,

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[3] Practice may vary, but many countries have regulations to the effect that candidates educated abroad will have to spend an equal number of years in state service after their return, i.e., two years for Master and three years for a PhD.

[4] http://worldwildlife.org/press_releases/salmon-aquaculture-dialogue-releases-environmental-and-social-standards

pollution, or labor conditions. In Norway, we see a rather positive NGO – aquaculture industry relationship emerging. While a few organizations seem to be absolutely against any type of commercial aquaculture, other organizations such as Bellona and WWF Norway are positive, even though there are clear conditions for this support.

Part of the problem, as seen from the foreign investor's point of view, may be to find out who the legitimate representatives of the local population are, knowing that local communities are seldom homogenous entities. Even within the smallest communities there are different interests involved, some powerful and some without much influence. Some interests may see a new aquaculture operation as beneficial, while others may find it harmful. This is especially the case where fishing (or farming) is an *occupation of last resort*, that is, an occupation for people having no or very few livelihood alternatives. In a poverty perspective, where access to food is vital, keeping common resources open may serve as an insurance policy, impeding the poor from falling into endemic (permanent) poverty. What is more troublesome, are international environmental NGOs (eNGOs) operating as self-styled protectors of local populations and interests. From Africa, we have seen a number of cases where eNGOs, in cooperation with central authorities, pretend to defend the environment, while ending up excluding both fishers and farmers from their livelihoods (Jentoft and Eide 2011). This may present a particular challenge to foreign supported activities, as these eNGOs are able to create considerable "noise" and bad press.

In order to demonstrate how these four main stakeholder groups operate, we shall provide a short summary of the development of the Norwegian salmon industry. This is not presented with the idea that other countries can replicate the Norwegian model, but in order to demonstrate how a successful interplay between the primary protagonists can create a major new industry within relatively few years.[5]

2.2 The Norwegian aquaculture system[6]

In 1971, the total Norwegian production of salmon was less than 1,000 tons, while in 2011 it had increased to more than 1 million tons. The pioneers no doubt played a crucial role, especially after starting with *salmon* in flexible *net pens* in the *sea*, instead of producing trout in soil dams on land. However, the Norwegian version of the aquaculture "miracle" is impossible to understand without a focus on the framing conditions, and in particular on the close connection between the farming industry, the regulatory authorities and researchers/educational institutions. Together they form a network which, in spite of conflicts and setbacks, has succeeded in creating an entirely new industry along the coast, offering direct employment to around 6,000 persons and an additional 12,000 persons in related support industries (feed, net pens, tubes, feeders, transport, banking, slaughteries, export, etc.).

[5] A similar story could be told about the organization of the Vietnamese *Pangasius* industry, which was created during a period of only ten years.

[6] The presentation is largely based upon Hersoug (2005).

In the 1970s, the interest in getting into this new and promising activity was so great that the authorities decided to set up a large commission to evaluate how the new industry should be developed and regulated. The commission soon realized that this task would take time, and in 1973 introduced a preliminary Aquaculture Act, limiting further access. The idea of using licenses came from the traditional capture fisheries, where concessions had been used to regulate the number of trawlers as well as purse seiners. Right from the start the goal was to use the new industry to create development and employment in rural areas along the coast, and it was decided that each owner could have only one (majority owned) farm. In addition, the authorities also regulated the size of the farm, originally 3,000 m^3, later to be expanded to 5,000, 8,000 and finally 12,000 m^3. Licenses were distributed according to political preferences in terms of areas (municipalities) and persons to be prioritized. After an initial moratorium, allocation rounds were made in 1981, 1983, 1985, 2003, 2004 and finally in 2009. The idea was to increase production according to what the markets could digest, based upon acceptable prices, but the license system was a rather crude regulation mechanism, especially as it takes three years from the seed to the sale of the finished product. Originally, both the production of fingerlings and the actual grow out operation were dependent upon a license system, but in 1985 the fingerling production was liberalized, immediately creating a rush of new entrepreneurs, and leading to overproduction and later to a crisis in the actual salmon production.

On the market side, the selling of salmon was made dependent upon a mandatory sales organization (the Norwegian Aquaculture Farmers' Sales Union - *FOS*)[7], based upon the same principles as found in the traditional catch fisheries. All fish had to be sold through the sales union, setting minimum prices and guaranteeing payment to the farmers. In 1991, a large-scale market intervention turned into failure, and the sales union and many of the farmers went bankrupt. Since that time, the selling of salmon has been done by independent exporters, associations of farmers or fully vertically integrated companies, even if the EU for years tried to introduce producer organizations (POs) – with no success. The bankruptcy of FOS and the liberalization of the sales functions did not create a free market for the Norwegian salmon producers. In 1997, the EU Commission introduced a Salmon Agreement in order to protect its own salmon industries (in Scotland and Ireland). The Salmon Agreement, continuing to 2003, fixed minimum prices, regulated the annual rate of export growth and introduced mandatory sales promotion of European salmon, in order to expand the market. The introduction of a 26 percent penalty tax on Norwegian salmon on the American **market i**n 1991 contributed to a situation where further development of the industry depended as much upon *external* trade conditions as the internal regulation of production. Hence, in 1991, the Norwegian Seafood Council was established to promote the sale of seafood on new as well as old markets. Originally, the funding of its activities was based on a 0.75 percent export fee, later to be expanded to 3 percent for all salmon export, thus facilitating both generic marketing of salmon as well as promoting Norwegian Salmon. The idea was to sell salmon, not as a luxury product but as a reliable commodity; "the chicken of the ocean."

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[7] All acronyms in *italics* refer to the Norwegian names.

While in the initial phase, there was some disagreement between the different ministries about who should have the primary responsibility for the new industry, and the outcome from 1977 onwards was that the Ministry of Fisheries became the lead agency. However, two other ministries still played central roles; the Ministry of Agriculture was responsible for animal health and veterinary services while the Ministry of the Environment dealt with area planning and pollution. Cooperation between the various ministries is now firmly established, but Norway has ended up with a rather complicated planning system, involving several ministries and three different levels of decision-making (central, county and municipality). In particular, the allocation of space has become complicated, with 276 coastal communities involved, each with their own set of priorities and responsibility for planning their sea areas.[8]

The key to success in fish farming is fish health, and Norway has had, from the mid-1980s, a system based upon veterinary control, originally performed by the county veterinarians, and from 2004 by the Norwegian Food Safety Authority. The veterinarians and the aqua-medicine biologists not only address diseases and treatment, but also provide advice on site locations, so that there are minimum distances from one farm to the other and between farms and slaughteries. While still not optimal (because ocean currents largely define the spread of pathogens), this system, combined with fallowing of sites and set-out of separate year classes, has reduced the frequency of fish diseases. Mandatory vaccination has further reduced fish mortality. Regulations pertain to the size of the farms, now regulated through a system of Maximum Allowable Biomass (*MTB*), stocking density and certification of all technical installations. Furthermore there are regulations regarding ownership, to the effect that no single owner may control more than 25 percent of the total amount of licenses, a regulation now being disputed by the EU. Nevertheless, salmon and trout farming take place along the entire coast (a distance of approximately 1,700 km), thus securing a degree of decentralization, no matter who the owner might be. Even with an area of more than 90,000 km^2 defined as interior waters (inside the base lines), lack of appropriate space is still considered a major challenge by the fish farmers. This situation has largely occurred because many coastal communities have not considered the payback from the industry sufficient to undertake major planning efforts. They have subsequently demanded an area or production fee, which has not been accepted so far.

When in 1991 the regulations regarding ownership were liberalized, concentration gradually developed to the effect that the industry today consists of a few very large companies, headed by Marine Harvest, a considerable number of medium-sized companies and a decreasing number of small companies with 1-5 licenses each. Economies of scale have been modest in the actual farming operations, while company size obviously influences both buying power and selling position, where the farmers often face very large retail chains.

Right from the start, the farmers have been organized, first in the sales union (*FOS*) and in the Federation of Norwegian Fish Farmers (*NFF*). When *FOS* went bankrupt, *NFF*

[8] Planning of sea areas is *voluntary*, and each municipality can plan its sea area out to the base lines plus one nautical mile.

stood alone for some years before the majority of fish farmers became members of the Confederation of Norwegian Enterprise (*NHO*) through a separate branch organization for aquaculture farmers and fish processors; the Norwegian Seafood Federation (*FHL*).[9] The important point is that the authorities at any point in time have been able to communicate with representatives of the fish farmers. They have not always agreed, but contact has always been close, thus securing benefits for both parties. Not least has this contact been beneficial when facing external threats, such as dumping and subsidy claims from the EU and the USA – conflicts that were ultimately solved largely due to close cooperation between farmers and aquaculture authorities.

Regarding the third component research and education, this activity has been central from the beginning. Fish farmers already established close contacts with researchers in the 1970s, finding that the previous trial and error approach was indeed very costly. In the 1980s, research and gradually education became prioritized areas of public policy, actively supported by government funding. In addition to public funding of universities, regional colleges and to some extent of research institutes, the research activities of the ministries involved have primarily been channeled through the Norwegian Research Council, thus coordinating efforts. Gradually, a larger part of research has been taken over by private companies, and in particular by the primary fish feed companies, operating their own research stations. A recent example of cooperation can be the mapping of the salmon genome, planned to be completed in 2013. This project has been financed by the larger companies in Norway, Canada and Chile, in cooperation with public research funding. Norwegian aquaculture has all along been characterized as an *open knowledge system*, where improvements are rapidly communicated and available for use. This has secured a very dynamic sector, with high flexibility and very high productivity.

The rapid increase in productivity and volume of the salmon farming since the 1980s has largely been dependent upon successful research into genetics, feed, fish diseases and vaccines, production technology, and gradually market research, while planning and management research has been lagging somewhat behind. Within education, all major universities are somehow connected to the education of personnel to the aquaculture sector. In addition, some of the regional colleges, the Norwegian Business School and the Norwegian School of Veterinary Science, produce candidates to the aquaculture sector (see chapter 4 for further details). What is characteristic for these lines of education is that they all have close contact with the industry during the entire study, securing relevance as well as job security for the new candidates after completing their studies. They may find their future employment within public management, education and research, sector organizations or in the actual farming companies. Former student networks have, on many occasions, proved very useful when facing new challenges, which often include interdisciplinary cooperation.

As can be seen from the brief history above, the Norwegian success is based upon close cooperation between authorities, farmers, research and educational institutions as well

[9] A splinter organization, *NSL*, organizes a number of smaller fish farmers/companies.

as representatives of civil society. This cooperation has, during the last 40 years, created a dynamic industry with considerable spin-offs in terms of producing supplies, transport, marketing, etc. The value chain is important as each job in the actual farming sector would in turn generate two jobs in various supply industries, ranging from transport to banking. Most of these activities take place in remote coastal communities, far from the capital. This is not to say that the history of Norwegian aquaculture is a history of peace and harmony. All along there has been strong tensions, first between agriculture and fisheries, later between small scale and large scale farmers, between a strong, mandatory sales arrangement and a liberal free market orientation, and between aquaculture farmers and other coastal interests, primarily fishers, recreational users (salmon fishers in particular) and conservationists. As per 2012, the extent of sea lice and escapees is so great that further expansion has been halted until fish farmers have found systems and remedies to reduce these threats, considered to be detrimental to the survival of the wild salmon. There is also a public discussion regarding the payback from the salmon industry to the local and regional communities. Thus, the issue of an *area fee* is being discussed in the Norwegian government.

Norwegian aquaculture is not an ideal system, but the way in which different actors have organized and cooperated has produced a blueprint or a model for how other nations aiming at using aquaculture for food production, poverty alleviation or as an important export sector could go around. Nevertheless, every country has to set up its own regime, depending upon the natural conditions, the fish to be farmed, the technological level, the political traditions, etc. Some elements may still be copied and adjusted to local conditions based upon Norwegian experiences, although they have been gained primarily through the farming of salmon and trout. However, many experiences are *generic,* and that is why the "Norwegian model" has something to offer to countries working under other conditions and with other species. The primary messages are that:

- Establishing a successful aquaculture sector depends upon a *systems perspective,* where several elements have to be seen in connection. (Solving one particular bottleneck may be important in a critical situation, but often this will only reveal a new bottleneck along the chain.)

- Private entrepreneurs, state authorities, research organizations as well as civil society organizations all have a role to play in the development of an aquaculture sector.

- Any aquaculture operation of size requires a sound planning system and responsibility for the allocation of space in order to avoid conflicts with other interests, whether in marine or inland waters.

- Furthermore, most modern aquaculture projects on an industrial scale require thorough investigation into fish diseases, subsequent treatment and precautionary measures. Extensive aquaculture will also benefit from an increased focus on fish health, thus reducing mortality and increasing profitability.

- Modern aquaculture needs qualified manpower, on different levels, hence close cooperation with educational authorities is required. With small-scale (extensive) aquaculture, an extension service will be required in order to connect scientists with widely dispersed farmers.

- In order to export to advanced markets, a quality oriented certification scheme has to be put in place, regulating the actual farming operations (fish health, environmental aspects, human health, etc.).

- Communication between different stakeholders is important in order to reduce conflicts. Hence, stakeholder organizations play a central role. These will facilitate contact between farmers and aquaculture authorities.

- Civil society plays a legitimate role regarding the establishment and administration of any sizeable aquaculture operation. If possible, CSOs should be included in planning new projects or programs from the very beginning.

- Conditions may vary considerably between countries, especially within the developing world. Hence, successful schemes cannot be copied directly. There is no "one size fits all." However, much can be gained from international standards and from "recipe books" describing best practices.

- In certain fields, such as fish health, vaccines, feed, etc., knowledge is to some extent *generic*, which means that experiences obtained in one country with a specific species, may easily be applied in other countries, working with other species.

Chapter 3

Critical factors in the aquaculture sector

In any aquaculture project there will be a number of potential critical factors. This chapter will focus on a few, based upon previous experiences and recorded project histories. They can be classified according to:

- Interventions in the natural environment and environmental impacts
- The introduction of new (alien) species in aquaculture
- The use of fish for feed (food fish, trash fish, off-al)
- Employment and food security
- Fish health
- The importance of institutional frameworks
- Investment climate and corruption
- Different management styles

Before discussing these critical factors, we should clarify the setting. They are all discussed within the framework of *industrial aquaculture*. As pointed out above, the Norwegian expertise is by and large developed within large-scale farming of trout and salmon. The relatively few companies and researchers having worked outside Norway have also been involved in large-scale farming of marine as well as fresh water fish. Very few have experiences from extensive, small-scale farming at the household or village level. This is also an area where especially Asia has superior and extensive expertise. This should, nevertheless, not be used to impede transfer of knowledge from the industrial to the artisanal sector. Both in the use of technology, feed, fish health, etc., the artisanal sector could benefit from adapting certain lessons from the industrial sector. It should be kept in mind that when the Norwegian salmon farming started in the late 1960s, it was also an artisanal sector, largely based upon trial and error by the original entrepreneurs and with little support from science.

3.1 Environmental impacts

Aquaculture practices have often had extensive influence on their surrounding habitats. For example, pioneering shrimp farms had negative impacts on mangrove forests in tropical countries. The building of ponds and modification of water flows and hydrological regimes of tropical estuaries for the aquaculture systems can have an impact on the life cycle and productivity of local fisheries depending upon those habitats. Fish farms are artificial elements in the coastal ecosystems, from cold temperate to tropical regions; cages for growing fish and seaweed, mussels, oysters and clams are grown on suspended ropes, racks or trays. These structures can occupy a substantial part of coastal space, to the detriment of other users, such as fishers.

Escapes of juvenile or adult fish are a constant possibility if operational or technical failures occur at fish farms. A single fish farm may hold hundreds of thousands to millions of cultured fish. In the Mediterranean Sea, approximately 500 million sea bass and 450 million sea bream are held in sea cages, with wild stock numbers believed to be considerably lower (ICES 2006). Similarly, over 300 million Atlantic salmon are held in sea-cages in Norway at any given time, which far outnumber the approximately one million salmon that return to Norwegian rivers from the ocean each year to spawn. In 2008 in Chile, the total production of salmonid species of 500 thousand tons there were about 180 million salmon (mostly Atlantic) in sea cages in southern Chile, where salmonids are not native. In some cases, due to the large numerical imbalances of caged compared to wild populations and in the difference in genetic makeup between farmed and wild species due to selective breeding, escape raises important concerns of ecological and genetic impacts.

Evidence of ecological effects on wild populations is largely limited to salmonids, as these interactions have been intensely studied, with more limited information for Atlantic cod and virtually no information for other species, including the major species farmed throughout the Mediterranean Sea (sea bream and sea bass). Impacts of escaped tilapia are less known, although De Silva et al. (2004) suggested that tilapia would tend to invade those freshwater habitats that have been degraded from various anthropogenic impacts, and made unsuitable for indigenous species.

Farmed fish can escape directly from net-cages and other enclosures due to human error, damage from a catastrophic natural event such as severe storms, or following damage to cage structures by predatory marine mammals. Some species of finfish and shellfish that spawn freely in captivity and produce pelagic eggs may release fertilized gametes into the surrounding environment. All these possible risks are believed to pose a greater threat to the natural populations than to other fish populations at large. This can happen during extreme weather events, as e.g., in China in 2007.

Whether a nutrient becomes a pollutant in an aquatic system is a function of whether it is a limiting nutrient in a given environment, its concentration, and the carrying capacity of that ecosystem. In fresh waters, phosphorus is typically the limiting nutrient (Hudson et al. 2000), so its addition will dictate the amount of primary production (algal growth). In marine environments, nitrogen is typically the limiting nutrient (Howarth and Marino 2005), so its addition will do likewise.

Soluble nutrients coming from digestion processes of farmed individuals will dissolve in the water column and their initial dilution and transport is a function of water current dynamics. Solid waste made up of uneaten feed pellets, feed fines (fine particulates caused by pellet damage during transport or automatic feeding systems) and fecal material can also accumulate below culture cages and in the outflows of aquaculture facilities. The accumulation will also depend upon the local currents and depth.

As nitrogen and phosphorus are released from fish cages and fish or shrimp ponds, there is always the potential for fish culture to promote eutrophic conditions; either by supplying a readily available nutrient source directly to phytoplankton; or oxygen removal, accompanied by nutrient release and via the decomposition of waste solids. High nutrient concentrations can also trigger algal blooms which reduce water clarity (and consequently sunlight availability in the water column to other organisms), and can strip oxygen from the water column when the organisms die, sink and decompose (Wetzel 1983).

Eutrophication, low oxygen events and fish kills affecting local fisheries are common events in some lakes and reservoirs in Asia where there is a high density of small scale fish cage farms that together produce excess nutrients in dissolved and particulate form and therefore going beyond the water body's carrying capacity (e.g., in Indonesia - Abery et al. 2005).

Organic enrichment of the seabed is the most widely known effect of fish farming globally. Such effects have been reported from various parts of the world such as Scotland (Brown et al. 1987), the East coast of Canada (Hargrave et al. 1993) or N.E. Pacific (Weston, 1990), Chile (Soto and Norambuena 2004), and the Mediterranean (Karakassis et al. 2000, 2005). This can impact benthic (e.g., sea grass beds) and sensitive habitats (e.g., corals) close to the farm (Holmer et al. 2008).

Like any land-based forms of raising livestock, where large numbers of animals are cultured at relatively high density, aquaculture can provide various diseases and parasites with the ideal conditions to spread. Antibiotics and other chemicals are administered to fish through medicated feed or through external treatments. Antibiotics can be spread to wild fish directly when they eat medicated feed that falls through the cages. This fish, in turn, may be caught and eaten by people, who thereby ingest limited doses of antibiotics (Røstvik 1997). This is undesirable, when one considers the development of resistance in humans. The general perception is that residues of these medications, however administered, will be absorbed by the benthic infauna and epifauna to their detriment, and bio concentrate up the food chain reducing the resistance to disease of demersal and pelagic fish and thus affecting fisheries.

Aquaculture production facilities should adjust their production to the carrying capacity of the local environment. Each ecosystem has a different capacity to absorb and assimilate excess loading of organic compounds and nutrients from a farm or capacity to absorb social changes, habitat modifications, etc., that come with the farm.

Aquaculture development should always be within the carrying capacity of the ecosystem. For example, an ecosystem approach would examine more carefully the desirability of different nutrient levels in different parts of an agro-fish-ecosystem from the perspectives of the various users, and in terms of the stability of the system as a whole. Thus, there needs to be a flexible and participatory approach to setting water quality standards.

Most modern fish culture involves more intensive input of nutrients in the form of feed, yet only a small proportion of these nutrients is actually converted into the target product, they can be largely lost to bacterial degradation. High levels of nutrients in effluent discharge to channels, rivers or lakes may cause eutrophication and affect fisheries adversely, but in other cases, depending upon dilution rates, effluents may be a beneficial addition of nutrients that boost natural productivity including fisheries. Modeling the nutrient budget could help find the optimal balance of nutrient release to enhance primary productivity to support wild fisheries.

Integrated aquaculture can be considered a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities and may be relevant in some circumstances. In this context, integrated multi-trophic aquaculture (IMTA) has emerged recently, in which multi-trophic refers to the explicit incorporation of species from different trophic positions or nutritional levels in the same system (Chopin and Robinson 2004).

3.2 The introduction of new (alien) species in aquaculture

As pointed out in chapter 1, aquaculture is an important activity in the coastal and inland areas of many developing countries. It offers opportunities to alleviate poverty, boost employment, enhance community development and food security, and reduces overexploitation of natural resources. However, many of the fastest growing aquaculture producers, both in marine and inland waters, use non-native or alien species. This is done mainly for two reasons: First, the use of familiar species may reduce the costs of research and development work, as much is already available, and can be obtained as "shelf commodities" (e.g., buying high yield fingerlings). Second, the markets for the already established species are available, while developing new markets for unknown indigenous species may take a long time and require considerable costs. Hence, for developing countries with the intention of using aquaculture either for food security or export purposes (or both), there are few incentives for using native species.

While the transfer of fish (and plants) is well known whenever groups of people have moved to new locations, it was first after WWII that the magnitude of such introductions became important and gradually the question of environmental health and biodiversity. Hence, much of the recent literature has focused on the negative aspects of alien species introduction. Here we are only going to comment on the *deliberate introduction* of fish and shrimp species in order to enhance production, not the accidental establishment of alien species as the result of releasing ballast waters, etc.

Introduced species may have environmental as well as social and economic impacts. Aquatic ecosystems may be affected by introduced species through predation, competition, mixing of genes, habitat modifications and the introduction of pathogens. The human communities may also be affected through changes in the fishing patterns or through changes in land use and not least, in terms of resource access, when new (and most often) high valued species are introduced into an arena. Table 3.1 offers a more detailed specification of the potential adverse effects.

Table 3.1: Potential adverse effects of alien species

Table 1. Some potential adverse effects of alien species		
Effect	Mechanism - Biological	Mechanism - Social
Reduction or elimination of aquatic species	Competition, hybridization, predation/herbivory, disease transmission	Change in fishing pressure and land use (accessibility); treatment measures
Change in terrestrial fauna	Change in abundance of preferred prey of waterfowl	Fish farms providing more food or killing predatory birds
Change in fishery management	Change in stock composition	Success breeds interest, failure breeds experimentation
Alteration in habitat	Burrowing, sediment mobilization, removal of vegetation	Change in land use, e.g., creation of fish farms
Socio-economic impacts	Change in species abundance or distribution to change fishing or consumption practices	Change in access rights, land tenure; financial liability for damages through national and international legislation

Source: FAO[10]

However, we should also note the benefits of species introduction. According to FAO approximately 17 percent of the world's finfish production is due to alien species. Furthermore, the production of the African tilapia species is much higher in Asia than in Africa (in 2010 2.5 million tons in Asia versus 645,000 tons in Africa). The introduction of salmonids in Chile supports a thriving aquaculture industry, responsible for approximately 25 percent of the world's salmon production and employing approximately 25,000 people directly and the same number indirectly in Chile's poorest southernmost regions.

The magnitude of introduced species can be illustrated through FAO's database on introduced species (DIAS), covering more than 5,600 introductions. Only for the three main types of tilapia, the database offers information of 200 introductions. De Silva et al. (2004) have evaluated tilapias as alien aquatic species in Asia and the Pacific, and their conclusion is that tilapias have made a significant contribution to food production, poverty alleviation and livelihood support. In addition, even more important: "In spite of the wide-scale introduction into Asian waters, there is scant explicit evidence to indicate that tilapias have been overly destructive environmentally" (ibid: IV).

[10] http://www.fao.org/fishery7topic/13599/en

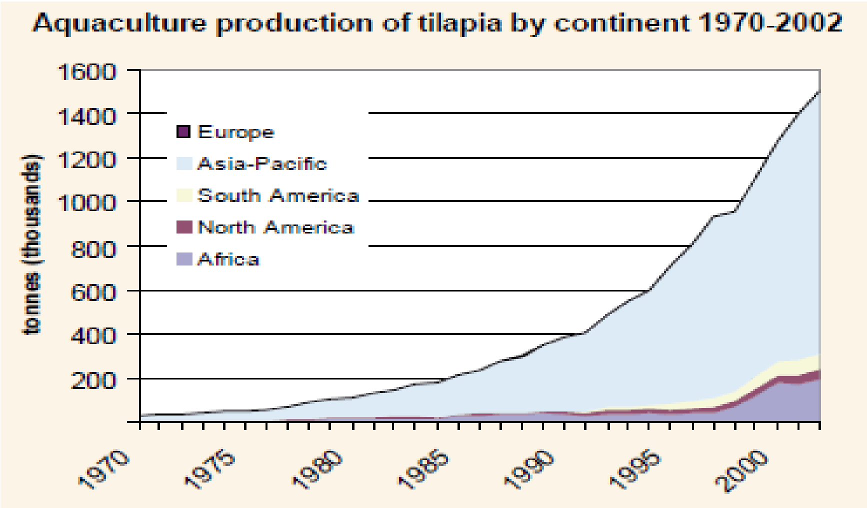

Figure 3.1: Aquaculture production of tilapia by continent 1970-2002.
Source: De Silva et al. (2004: 32).

As can be seen from the figure above, the aquaculture production of tilapias has been a recent development beginning in the 1970s with the take-off phase in the 1980s. From figure 3.2, we also see that major development has taken place in Asia, and in particular in China, being by far the largest producer, followed by the Philippines, Indonesia, Thailand, and Taiwan.

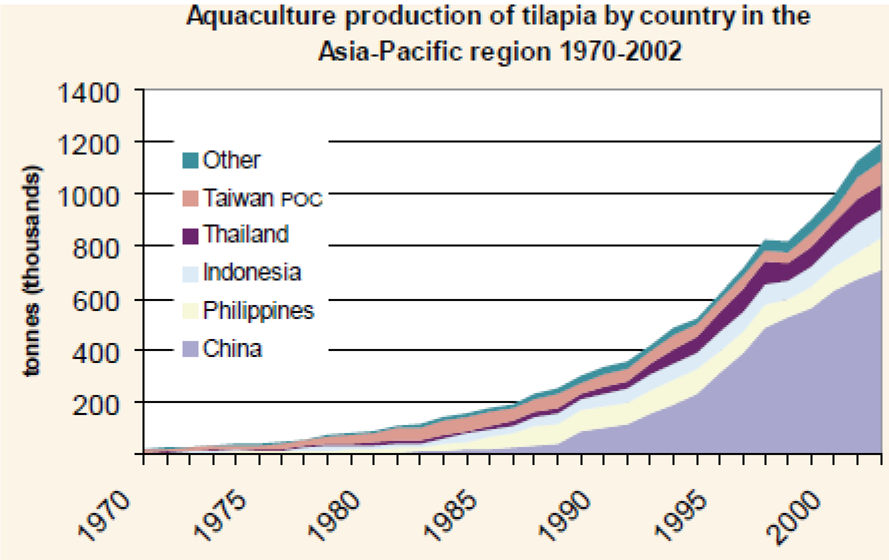

Figure 3.2: Aquaculture production of tilapia by country in the Asia-Pacific region 1970-2002. Source: De Silva et al. (2004:35).

The enormous increase in tilapia production can largely be attributed to the genetic improvements made through ICLARM's development project: Genetic Improvement of Farmed Tilapia (GIFT). The GIFT fish has proved superior to all other tilapia strains and is today widely used throughout Asia.

Somewhat less fortunate has been the introduction of alien shrimp species. The primary reason behind the importation of *P. vannamei* to Asia has been the perceived poor performance, slow growth rate and disease susceptibility of the major indigenous cultured shrimp species, *P. chinensis* in China and *P. monodon* virtually everywhere else. However, for many reasons, particularly with the evidence of the introduction of exotic viruses to the region, there has been caution on the part of many Asian governments towards the introduction of *P. vannamei* and *P. stylirostris*. Such precaution has not been demonstrated by the private sector, which has been bringing stocks of illegal and often disease carrying Vannamei into Asia from other locations, as well as moving infected stocks within Asian countries. The commercial success of these introductions, despite disease problems, has allowed the development of large shrimp industries within Asia, and particularly in China and Thailand (Briggs et al. 2004).

What these two case stories illustrate is that the practice of using alien species will most likely continue. The issue is not to ban alien species (or to eradicate them, which is for all practical purposes impossible), but regulate the introduction, preferably by assessing associated risks and benefits, and then, if appropriate, developing a plan for responsible use. One mechanism to assist in the responsible use of introduced species is the development of codes of conduct, such as have been developed by the international Council for the Exploration of the Sea (ICES) and the European Inland Advisory Commission (EIFAC).

The basic Code requires that:

1. "The entity moving an exotic species develop a PROPOSAL, that would include location of facility, planned use, passport information, and source of the exotic species;
2. an independent REVIEW that evaluates the proposal and the impacts and risk/benefits of the proposed introduction, e.g. pathogens, ecological requirements/interactions, genetic concerns, socio-economic concerns, and local species most affected would be evaluated;
3. ADVICE and comment are communicated among the proposers, evaluators and decision makers and the independent review ADVISES to either accept, refine, or reject the proposal so that all parties understand the basis for any decision or action, thus proposals can be refined and review panel can request additional information on which to make their recommendation;
4. if approval to introduce a species is granted QUARANTINE, CONTAINMENT, MONITORING, AND REPORTING PROGRAMMES are implemented, and
5. the ONGOING PRACTICE of importing the (formerly) exotic species becomes subject to review and inspection that check the general condition of the shipments, e.g. checking that no pathogens are present, that the correct species is being shipped."[11]

Similar schemes have been developed by IUCN[12] and other environmental NGOs.

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[11] http://www.fao.org7fishery/topic714782/en

3.3 Fish diseases

Rearing aquaculture species at high densities under artificial conditions allows for considerable risks of losses from outbreaks of infectious diseases. In Norwegian salmon farming, which can be regarded as both successful and efficient aquaculture production at a global perspective, approximately 15-20% of the total numbers of fish transferred to sea die before they reach the slaughter-bench and infectious diseases are a major player here. It is estimated, for example, that the annual loss in the Norwegian aquaculture due to viral diseases is approximately 1.5 billion NOK.

Bacterial and viral infections constitute the most important source of disease in aquaculture production and some of the diseases caused by these pathogens may cause extensive mortalities. There are numerous examples of highly virulent bacterial or viral diseases that have caused serious losses and long-lasting damage in aquaculture production, i.e., infectious salmon anemia virus in Atlantic salmon and Koi herpes virus in common carp. Additionally, fungal growth on the surface of eggs and larvae of fish and shellfish can cause direct mortalities. Fungi also occur as common secondary invaders in wounds and lesions caused by, for example, bacterial pathogens. Wild fish and shellfish are normal hosts to a wide array of parasitic forms. In nature, hundreds of species have been reported from fish and shellfish, but the survival of these populations are seldom affected by parasites. However, under aquaculture conditions, where the fish are crowded together in a small area, such parasites may more seriously affect the fish. An example is the salmon louse, which is causing significant economic losses in commercial salmon and rainbow trout aquaculture. Parasites are feared in aquaculture, both because they are difficult to treat with drugs and good vaccines are not available, and for some, they might also induce human diseases.

Infectious diseases can spread more easily within dense populations simply due to increased opportunities for transmission. However, diseases are not unique to aquaculture operations; any high-density animal production results in high disease prevalence. One major difference between aquaculture and terrestrial animal production is the level of confinement. Contact between domestic and free ranging wild animals of the same or closely related species is easily monitored and controlled in terrestrial animal farming. Ocean based aquaculture is an open system where farmed fish may incubate and transmit infectious agents to and from wild fish. Good surveillance systems as well regulatory instruments by the authorities are prerequisites for controlling infectious diseases. Obviously, there is a need to develop prophylactic and therapeutic strategies to decrease losses as well as the spread of pathogens to the wild population when new species are introduced to aquaculture production.

The environmental factors such as ample amount of fresh oxygen and maintenance of good water quality are parameters that should be controlled to reduce morbidity and mortality. Traditional efforts comprise prevention of contamination with infectious agents from other farms, and external contamination through personnel, water streams or equipment. Vaccines

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[12] http://www.iucn.org/about/work/programmes/marine/marine_resources/marine_publications/?1226/Alien-Species-in-Aquaculture-Considerations-for-Responsible-Use

both against bacterial diseases and to some extent against viruses are most likely the single factor of greatest importance for successful fish farming today in all types of industrial aquaculture.

With a successful fish health control system, Norway has been able to increase production of farmed salmon ten times and reduce the total use of antibiotics by 95percent. New farmed fish species demand new reagents and new control strategies. Only extensive research can follow the industry's progress trying to solve the disease problems as they appear. New viruses have appeared regularly in Norwegian aquaculture, and intensive farming introduces a large burden on the natural defense system of the fish. Once again, we see that an intensive collaboration between different scientific fields, including breeding, pharmacology, immunology, microbiology, pathology and nutrition, are necessary to solve the most pressing problems in modern aquaculture.

3.4 The use of fish for feed (food fish, trash fish, off-al)

Over the last ten years, there has been an increasing debate over the sustainability of aquaculture production, and in particular using wild fish for the production of aquaculture fish. Critics have questioned the use of fishmeal and fish oil in aquaculture production, and claimed that these resources should instead be used directly for human consumption. The debate is complicated, but much research has been done addressing the various sustainability issues. The most comprehensive review so far has been presented by Hasam and Halwart (2009).

The starting point is how much fish is used for the production of fishmeal and fish oil. As can be seen from figure 3.3, the production of feed fish has declined since 1994, both in absolute numbers and as a percentage of the total catch. Total fishmeal production ranges between 5-7 million tons a year, while fish oil is stable around 1 million tons (FAO 2009; Tacon and Metian 2009a, b: EWOS 2010).[13] However, the distribution of fishmeal has completely changed over time; in 1980, about 100 percent was used in agriculture, while this share decreased to 40 percent in 2008 (Jackson 2010a, b). The primary market for fishmeal today is the aquaculture industry, where the production of salmon, shrimp and finfish consumes most of the available fishmeal and oil.

Species used for fishmeal and fish oil are so-called forage fish, which are characterized by being short-lived, small and fast growing (Fréon et al. 2005). Such species are in general pelagic and move in large schools. Forage fish are not that prone to overfishing as, for instance, benthic fish because of their short lifespan and population doubling time (Shepherd et al. 2005). Forage fish are in general not perceived suitable for human consumption because they are small, bony, soft, fragile, and prone to rancidity and spoil easily (James 1995).

[13] According to FAO (2012), the wet fish equivalent was 30.4 million tons in 1994, which has decreased to 15 million tons in 2010.

However, there is potential for some of the species to be destined for consumption markets.

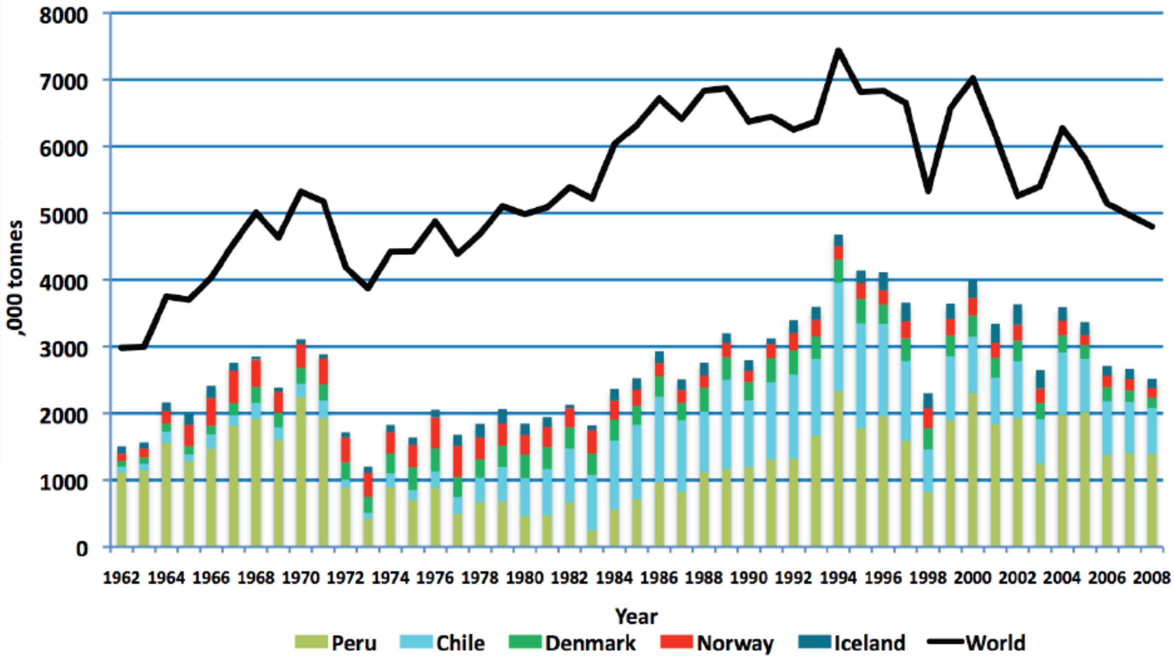

Figure 3.3: World fishmeal production 1962-2008. (Source: Jackson 2010)

In most cases, it is not economically sustainable with processing because forage fish need rapid handling and processing which requires heavy infrastructure. In addition to this, it should be mentioned that FAO (2012) estimates that approximately 36 percent of the fish meal production came from offal in 2010. Indications are that this development will continue. A study on the limited supply of fishmeal and its impact on future increase in global aquaculture production, indicates that five important aquaculture species will have a reduced fish meal level down from 23 percent (1995) to 5 percent predicted for 2020 (Olsen and Hasan 2012).

There are various reasons why aquaculture may seem more sustainable than its critics claim. The first refers to the energy conversion. Fish, and in particular salmon, appear to be absolutely the most efficient animal in terms of consuming fish feed relative to eatable meat. Second, over the last ten years there has been a dramatic decline in the use of fish in fish feed in general, and to finfish in particular. Up to 70 percent of the feed has been substituted by plant ingredients (soya), without removing the important Omega 3 fat acids. Third, fish feed can also be produced by offal. In the EU, one third of the fishmeal is produced based on offal from the traditional catch fisheries, while in Norway the percentage is somewhat lower. In Norway, the conversion rate is now between 1.2-1.3 kilograms feed per kilogram-produced salmon, indicating that between 1.5-2.2 kg forage fish and fisheries offal is needed in the feed. This is substantially down from the past 10-20 years and clearly lower than the global “fish in-fish out” (FIFO) average level of 5:1 (Pihlstrøm 2010). Fourth, in Asia much of the feed is produced from trash fish and by-catches, which even when sold very cheap is not considered to be suitable for human consumption. Finally, the prospect of aquaculture out-competing the agricultural industry in terms of feed consumption is not only negative. Fish is definitely better for health reasons than, for example red meat, and even more important, fish from aquaculture consumes very limited amounts of fresh water, compared to livestock, sheep or even poultry. In total, the fear that aquaculture would not be able to expand further, due to lack of feed, seems to be somewhat exaggerated. Seen from a climate change perspective, a shift in fishmeal use from livestock to aquaculture can also be seen as positive. There are however, also other considerations.

The sustainability issue refers to various dimensions, where the ecological effects are considered to be the most important, while food security and social concerns also play a central role. The ecological effects refer primarily to whether the feed fisheries are sustainably managed. Based upon FAO's assessments and Pihlstrøm's (2010) assessment of Norwegian aquaculture, most stocks used for the feed industry seem to be fairly well managed. As can be seen from figure 3.3, the two largest producers are Peru and Chile, and in spite of reasonably good management, the annual variations may be great. In the case of Peru, anchoveta harvests may fluctuate between 1 and 10 million tons per year. The ecosystem effects refer to the actual stock dynamics, and the need to allocate a certain part of the resources for seabirds and marine mammals. Overfishing may harm not only the target stock, but also sea birds and marine mammals, and in the end contribute to major changes in the actual ecosystem as well. The social dimension of sustainability refers to the use of these feed fish resources and their ability to create work and income for the people involved, and in particular for poor people. Pihlstrøm (2010) has demonstrated that there may be several reasons why certain species are not destined for human consumption: relating to quality, price, distance to market or simply cultural preferences regarding food. Wijkström (2009) states that *the poor in most parts of the world do not obtain more (or less) cheap fish because forage fish is utilized in aquafeed*. In Asia, the practice of feeding farmed fish with wild fish, harms some of the poor, but is beneficial for others. It is also pointed out that the main problem in this area is the use of by-catch or trash-fish in aquaculture operations. This reduces the amount of fish available for food and the chances of creating employment (Wijkström 2009). Hasan and Halwart (2009) present a sound conclusion of the investigations carried out so far:

> In summary, there is no single "answer" as to whether more use of feed fish should be made for human consumption. To answer this question requires a regional approach that examines all the consequences – economic, social and environmental – of policy change to ensure that inappropriate solutions are not rushed through on the back of simplistic assertions (ibid: 50).

3.5 Employment and food security

Just as in traditional capture fisheries, aquaculture is normally promoted to achieve central goals, such as increased income from fish exports, increased availability of fish for local/regional/national consumption (food security), to generate employment and to increase income among poor segments of the population. As pointed out by Bailey and Jentoft (1990), the choice between these goals can often be characterized as "cruel" or hard choices. Very seldom can all four be fulfilled at the same time. Normally we will have to make a trade-off between them, because increasing income could easily lead to reduced employment and vice versa, and fish for export can hardly be used for local food consumption. All fishing (and aquaculture) nations make such trade-offs or compromises, but they are seldom explicitly made. Fish, whether wild or from aquaculture, can basically be used in two different ways: you can farm the fish and eat it, or you can farm the fish, sell it and use the income for food. In the case of export, this means that you can be able to import other basic foodstuff as well.

From the authorities' point of view, most large-scale aquaculture activities are motivated by generating employment and income in addition to surplus from export. In many developing countries, fishing has been an "employer of last resort," that means a sector with low entry barriers and easy to access for people with few other alternatives. However, in most of these countries, the wild fish stocks are fully utilized and further increasing the number of participants can only reduce the income of the current participants and, in the long run, reduce the chances of fishing in a sustainable manner. Hence, many nations have deliberately started with aquaculture in order to provide alternative employment for large coastal or inland populations. This applies to countries such as India, Vietnam, China, Bangladesh, Thailand, Myanmar and Indonesia, as well as smaller nations like Malaysia and Uganda.

Fish is therefore for many developing countries the most important cash crop (more important than a number of agricultural cash crops such as coffee, cocoa, rice, etc.). When traditional primary products experienced a slump in the global markets, fishery products, originating from capture or from aquaculture, became even more important. Fish is not only considered as a force in generating export income, but also seen as a solution to empowerment and poverty problems as well (MOFI 2000). Fish can be turned into cash within a very short time, and does not involve the large development costs most often found in agriculture or mining. When leasing out fishing , the state does not have to invest at all (except for monitoring).

This development in world trade with fish can be seen in perspective when noting that development aid to fisheries and aquaculture is calculated to be in the order of US$15 million per annum in the 1970s, US$425 million in the 1980s and US$1,312 million in the 1990s, that is, less than 5 percent of the total export value (measured in US$) (Kurien 2004). Another way of placing the development efforts into perspective is to calculate the terms of trade of the fish products delivered by developing countries. From Kurien's (2004) calculation of shrimp export, it appears that due to deteriorating export prices from 1996 compared with 2001 (the WTO-period), developing countries "lost" more than US$1 billion, or close to the annual amount spent on development aid in the fisheries.

While aid is still important, international trade in fish and fish products is the primary force behind fisheries development over the last decades. While marine fisheries were the most important in the first period (including the 1980s), aquaculture is rapidly becoming the largest supplier of fish for human consumption. As pointed out previously, fish can be used for direct consumption or for export (or for both). Recently there has been an increasing awareness of fisheries development channeling previous supplies for local and regional markets over to export markets, thus aggravating the food security situation. This awareness has in particular been spurred on by the well-known case of the Lake Victoria fisheries for *Nile Perch*, which in the 1970s and 1980s were a great source of protein for the region. In the

1990s, these fisheries became largely export-oriented with detrimental effects on food security for the local and regional communities (Jansen 1997; Abila and Jansen 1997). Kurien's (2004) study of global development trends as well as eleven selected case studies shows that the Lake Victoria example *is not representative* of developing countries participating in the world trade of fish and fisheries products. The Low Income Food Deficient Countries (LIFDCs) still export only 8.8 percent of their total catch. Even if we adjust for the effect of China the figure is still only 14.7 percent. Hence, there seems to be merit in the conclusion that there are "consequently no supply constraints to achieve direct food security" (Kurien 2004:17).

This does not mean that the situation is unproblematic. If we take a closer look at the non-LIFDCs, that is, the remaining developing countries, their share of the export has actually increased from 37.7 percent in 1976 to 64.8 percent in 2001. Whether this is "good" or "bad" can only be decided by studies at the local level. This is precisely what Kurien (2004) has done, showing that in certain countries the effects of increased trade in fish have been positive for the nation, the fishers, the fish workers and the consumers. This is the case for countries such as Namibia, Chile, Sri Lanka, Fiji, Nicaragua and Thailand, while the positive effects have been few in countries such as Senegal and Brazil. The effects have been negative and few in countries such as the Philippines and Kenya while the effects have been negative and significant in Ghana. Even if the methodology used in this study is admittedly primitive (scoring on five dimensions based upon country reports produced by local consultants) the message is important: The effects of increased international trade with fish cannot be assessed on a global level. National or even local analysis is required to see how trade is affecting various groups of stakeholders, the resources and ultimately the ecosystem.

One particular issue of concern is the fact that most developing countries are only exporting a narrow range of species. This is especially the case with LIFDCs, which are locked into a limited product and process specialization. Over the last 25 years crustaceans, mollusks and cephalopods have accounted for 58 percent to 72 percent of the exports, while fish counted for only 8 percent to 30 percent in the same period (Kurien 2004).

From a food security perspective, this may seem to be good news; eating fish at home and exporting the luxury items, which has been the strategy in countries such as Mozambique and Angola. However, if we include entitlements to food (obtained through salaries, etc.) the small range of products and the deteriorating terms of trade are a direct threat to developing countries having concentrated their efforts on such production. This is even more so when we look at the tendencies to market and importer concentration, which leaves more and more power to the importers, normally at the expense of the exporters and in the last instance, of the fishers or aquaculture farmers providing the products. An additional warning from Kurien (ibid) is that the positive effects of trade are not necessarily benefiting those who are directly involved in the front line as fishers, fish farmers and fish workers. Benefits tend to be heaped on certain segments of the population while others seem to get more than their share of disadvantages.

3.6 The importance of institutional frameworks

Aquaculture raises legal and institutional issues, as it is an activity that affects humans as well as natural resources, and in the end, the entire ecosystem. Aquaculture is dependent upon land, water and aquatic species, and may also cause substantial environmental changes. On the social side, these environmental changes may in turn cause social and economic changes. In addition, aquaculture produces products (fish) that should be safe for human consumption, both in domestic and foreign markets. Consequently, the management of aquaculture is likely to fall under the scope of legislation and expertise of various institutions (Van Houtte 2001). The law of aquaculture is therefore a rapidly emerging field, where new aspects are added to old regulations, often requiring institutional changes. Given that most governments try to promote *sustainable aquaculture*, laws and regulations play an important part, but as pointed out by Van Houtte (2001: 103), law is only one amongst a number of mechanisms that may be required to secure this objective: "Any belief that a legal prohibition of unacceptable behavior will solve an environmental concern is erroneous."

Even if aquaculture is an old, established activity, especially in Asia, specific laws regulating the activity have only been developed over the last 25 years. Such laws may, as in Norway, appear as a specific aquaculture act, or they may be developed under existing fisheries regimes, under water regulations or as part of environmental regulations. The laws and institutional frameworks regulating aquaculture comprise the actual regulation of space, the operations of the farms, fish health control, product control, as well as regulation of markets and exports. The use of genetically modified organisms (GMO) may also affect the aquaculture regulations. Here we are going to concentrate on the initial areas: the establishment of aquaculture activities (farms) and the laws and regulations affecting the actual operations.

While the type of aquaculture may vary greatly (fresh water, brackish water, marine waters, public/private ownership, etc.), all laws and regulations contain a definition of what is meant by aquaculture. According to FAO's review, these may differ considerably from one country to another, but the following generic definition, offers a good starting point to differentiate aquaculture from fisheries:

> *Aquaculture* is the *farming* of aquatic organisms including fish, mollusks, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the *stock* being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to *aquaculture* while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of *fisheries* (The Aquaculture Steering Committee of the Fisheries Department, Van Houtte 2001).

The actual establishment of aquaculture activities will in most cases be governed by a license, a concession or a lease. This is, however, no guarantee that the site is well suited for farming. Even in countries requiring an environmental impact assessment, the location of farms has proved detrimental, largely due to the large number of farms in the same area. If fish health is considered the primary factor behind any successful aquaculture operation, the siting of farms becomes imperative. Good planning systems are not in place in most developing countries and, as indicated in the next chapter, this is an area where Norway can contribute. This also applies to laws and regulations regarding the operation of the farm. For evident reasons, farming conditions will depend not only upon the type of fish or crustacean (shrimp, lobster, etc.) but also upon the legal tradition in the country. Over time, there is a trend towards more equal regulations, as a result of three different but closely related developments:

- Voluntary and mandatory requirements of a number of international instruments with relevance for aquaculture, such as FAO Code of Conduct for Responsible Fisheries; Convention on International Trade in Endangered Species of Wild Fauna and Flora; Convention on Biological Diversity; WTO; OIE; Codex Alimentarius Commission of FAO/World Health Organization).
- Specific criteria regulating access to major import markets, such as Japan, the USA and the EU.
- The impact of environmental NGOs working with various certification schemes (e.g. Aquaculture Stewardship Council (ASC)).

The importance of having a good regulatory framework can hardly be exaggerated. FAO (2011) has summarized the key issues of importance for aquaculture policy implementation, which are spelled out in table 3.2.

Table 3.2: Key legislative issues of importance for aquaculture policy implementation

1. Non-aquaculture-specific legislation should be considered for its support or hindrance to aquaculture policy implementation, as well as for its relationship to aquaculture-specific legislation.
2. A legal framework supportive of policies and supported by stakeholders is more likely when stakeholders are involved in the process to develop legislation itself.
3. Aquaculture policies should ideally ensure that aquaculture legislation is supportive of them before related activities are commenced, and if not, appropriate legislative changes should be sought.
4. Aquaculture legislation should contain dispute resolution mechanisms to deal with user conflicts and to ensure that local rules and regulations do not conflict with national-level legislation and policies.
5. Aquaculture legislation should specify the extent to which local autonomy in developing management rules and legislation will be accepted.
6. National aquaculture legislation should provide for a broad and flexible framework that enables a choice of strategic options, with detailed mechanisms set out in regulations that can be changed if necessary.
7. National aquaculture legislation may need to contain specific reference to certain key concepts (e.g. ecosystem approach to aquaculture) or to provide indirect support to key success factors that need legislative support (e.g. decentralization, and definition of boundaries).
8. Aquaculture legislation needs to ensure the security and enforceability of a right, and the ability and opportunity for rights holders to seek redress for violation of security and interests in the rights allocated.

Source: FAO (2011: 90), after Macfadyen, Cacaud and Kuemlangan (2005)

3.7 Investment climate and corruption

There is nothing specific with aquaculture compared to other food commodity producing sectors, except that the turnover is quicker, thus attracting investors that are eager to earn the "quick bucks." Fish farming can produce a cash flow after only one year, provided that equipment can be bought as a turn-key operation, and that fingerlings can be bought on the open market. Another advantage (at least with most marine aquaculture) is that equipment can be moved to another site or in extreme cases to another country. There are consequently less *sunk costs* involved in aquaculture compared to many other industries.

The term *investment climate* refers to a number of factors, first and foremost related to the security of investments. All entrepreneurs would like to see that their investments are secure from sudden confiscation and from undue limitations, such as new licensing requirements, etc. One of the reasons why Chile was so attractive to foreign aquaculture investors, was that foreign capital investments faced nearly no obstacles. There were no restrictions on foreigners, no ownership limitations, no maximum limits in terms of aggregated ownership, and a generous scheme for repatriation of profits. Repatriation of profits is of course a major theme for all foreign investors, and an area that differs largely from one developing country to another. Regarding aquaculture investments, we find very different regimes, from the ones allowing tax-breaks and 100 percent repatriation to the ones claiming full taxes from the first year and very limited possibilities for capital export (of profits). For prospective Norwegian investors such rules may be decisive, while for traditional development assistance projects the investment climate is of limited interest. However, regarding corruption this may be detrimental to both types of projects. Corruption destroys the credibility of any development project, whether privately or publicly funded. Corruption is rife in a number of countries that are potential Norwegian partners, and it would be naïve not to expect attempts of corruption also in the aquaculture sector. It should nevertheless be stressed that corruption is not a phenomenon found only in developing nations. Also on the donor side, there has been mismanagement of funds and attempts of channeling aid and grants in specific directions. For both partners, transparent procedures should be established from the beginning, including auditing, monitoring and reviews, thus reducing the chances of corruption.

3.8 Different management styles

Most Norwegian fisheries and aquaculture experts, whether working in private companies or public agencies, are known for their practical attitudes, "hands on" approach and ability to do a number of different work tasks, including the ones considered to be simple. This has no doubt led to increased efficiency in Norwegian aquaculture and to close connections between farmers and researchers, thus being able to notice challenges on short notice, and to implement new solutions without delays. However, this management style is not always considered to be appropriate in a number of developing countries, where the hierarchical structure is much stronger, and where experts do not perform practical work. In many developing countries, including middle-income countries such as Chile, Norwegian experts will have to adapt to a different management regime. Here, the typical Norwegian strengths, such as informal style, direct communication and hands-on-approach will not attract the same praise as at home, underlining the need also for Norwegian experts to be more familiar with the work regimes of the partner countries. In Kerala, the old saying was that "to be a Norwegian, you have to be an expert" (Hersoug et al. 2004). This is no longer a guarantee.

3.9 Summary

- Norwegian expertise is by and large developed within large-scale farming of trout and salmon. Very few have experiences from extensive, small-scale farming at household or village level. This should, nevertheless, not be used to impede transfer of knowledge from the industrial to the artisanal sector. Both in the use of technology, feed, fish health, etc., the artisanal sector could benefit from adapting certain lessons from the industrial sector.
- In any aquaculture project there will be a number of potential critical factors. Some of these risk factors may be mitigated through careful planning.
- Aquaculture practices have often had extensive influence on their surrounding habitats. Integrated aquaculture can be considered a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities and may be relevant in some circumstances.
- Bacterial and viral infections constitute the most important source of disease in aquaculture production and some of the diseases caused by these pathogens may cause extensive mortalities. There is a need to develop prophylactic and therapeutic strategies to decrease losses as well as spreading of pathogens to the wild population when new species are introduced to aquaculture production. Vaccines both against bacterial diseases and to some extent against viruses are probably the single factor of greatest importance for successful fish farming today.
- Many of the fastest growing aquaculture producers, both in marine and inland waters, use non-native or alien species. This is done in order to save development costs and to utilize existing markets. Introduced species may have environmental as well as social and economic impacts. However, the benefits are substantial, e.g., in producing tilapia. The issue is not to ban alien species, but to regulate the introduction, preferably by assessing associated risks and benefits, and then develop a plan for responsible use.
- Over the last ten years, there has been an increasing debate over the sustainability of aquaculture production, and in particular of using wild fish for the production of aquaculture fish. The debate is complicated, but recent research does not indicate that the poor in most parts of the world will obtain more (or less) cheap fish because forage fish is utilized in aqua feed.
- While aid is still important, international trade in fish and fish products is the primary force behind fisheries development over the last decades. Recently there has been an increasing awareness of fisheries development channeling previous supplies for local and regional markets over to export markets, thus aggravating the food security

situation. Detailed research from many fish exporting countries does not support this description, as there are no supply constraints to achieving food security.

- Aquaculture raises legal and institutional issues, as it is an activity that affects humans as well as natural resources, and in the end, the entire ecosystem. The law of aquaculture is therefore a rapidly emerging field, where new aspects are added to old regulations, often requiring institutional changes. Given that most governments try to promote *sustainable aquaculture*, laws and regulations play an important part, but law is only one amongst a number of mechanisms that may be required to secure this objective. The actual *implementation* of laws and regulations is presently the main bottleneck, largely due to lack of human as well as financial resources.
- The term *investment climate* refers to a number of factors, first and foremost related to the security of investments. All entrepreneurs would like to see that their investments are secure from sudden confiscation and from undue limitations, such as new licensing requirements, etc. Corruption destroys the credibility of any development project, whether privately or publicly funded. Corruption is rife in a number of countries that are potential Norwegian partners, and it would be naïve not to expect attempts of corruption also in the aquaculture sector.
- Most Norwegian fisheries and aquaculture experts are known for their practical attitudes, “hands on” approach and ability to do a number of different work tasks. In many developing countries, Norwegian experts will have to adapt to a different management regime. Here the typical Norwegian strengths will not attract the same praise as at home, underlining the need also for Norwegian experts to be more familiar with the work regimes of the partner countries.

Chapter 4

Discussing the relevance of Norwegian competence in different areas of the aquaculture sector

As pointed out in the introduction, most of the Norwegian competence in aquaculture has been developed in connection with salmon and trout farming in Norway, starting in the late 1960s and reaching an industrial phase in the 1990s. Relatively few Norwegian companies have been directly involved in aquaculture operations in developing countries, with important exceptions (Vietnam, Malaysia, China, Philippines, Belize, Honduras, Nicaragua).[14] Some of these companies have had Norwegian managers placed on the site for a long period, while others have relied upon local management, assisted by short-term follow-up missions by Norwegian personnel. More companies have been involved in the delivery of equipment, input factors such as feed and vaccines and consultancy services. A number of Norwegian researchers have also worked with various aspects of aquaculture in different countries, ranging from development of feed to sector management. However, very few Norwegian aquaculture experts have been permanently based in developing countries for a number of years.[15] This means that the technical expertise may often be excellent, while the *country-specific competence* lags somewhat behind, thus complicating the actual adjustment: How to transform the expertise obtained largely in Norway to the local setting in the developing world?

Before assessing the relevance of Norwegian competence, relative to the aquaculture sector in the developing world, we need to note some qualifications. Norwegian expertise has primarily been developed in relation to *industrial aquaculture,* which in the Norwegian setting is the basis for an export sector (95 percent of Norwegian salmon and trout go to the export markets). When discussing relevance, we anticipate that Norwegian expertise will also be used primarily for industrial or semi-industrial production in developing countries. Expertise in extensive, small-scale fish farming for local household needs is not a Norwegian specialty, and in this field most of the traditional Asian producing countries have the best expertise themselves (e.g., production of carp in dams). *This does not imply that Norwegian expertise should be used exclusively for industrial projects.* Generic knowledge regarding

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[14] Chile is in this context considered a "middle income country". After heavy Norwegian involvement in the 1980s and 1990s there are now two remaining producer companies in Chile (Mainstream and Marine Harvest), being responsible for ca. 12 percent of total production in 2011. Aquagen (Norwegian based but majority owned by German interests) is involved in the production of fingerlings in Chile. Ewos (owned by Cermaq) is among the main producers of fish feed.

[15] The obvious exception is Chile, where Norwegian experts have been more or less permanently based since the mid-1980s, but gradually in decreasing numbers. However, as indicated above Chile no longer qualifies as a typical developing country.

seed production, fish feed, fish diseases, vaccines, etc., may be both relevant and highly beneficial if applied also to small-scale production, preferably via networks organized through extension service. In the following, we shall very briefly deal with the different aspects of aquaculture and see where Norwegian expertise can make its most important contributions.

4.1 Management and legislation

Norway has initiated and participated in a number of projects developing fisheries laws and regulations – recently also related more specifically to aquaculture. Expertise is found in the Ministry of Fisheries and Coastal Affairs, the Directorate of Fisheries and not least in FAO. This is a highly specialized field of expertise with a limited pool of experts available in Norway.

Regarding the more general theme of establishing new management structures, the University of Tromsø has for years worked with the institutional set-up of fisheries management institutions in Africa, Latin America and Asia. The same applies to the University of Bergen and the universities of Oslo and Trondheim (*NTNU*). The Directorate of Fisheries in Bergen has also been specifically involved in developing laws, regulations and management institutions in various countries, most recently in South Africa and Vietnam. As for a number of areas mentioned below, most of these institutions have a capacity problem, as they are all heavily involved in management, teaching and research within Norwegian aquaculture, and seldom have spare capacity, except for the fisheries development unit of IMR (CDCF). However, several of these institutions could be interested in monitoring specific projects, provided that research is built into the project from the start. Lack of available capacity is a general problem for the management institutions (ministries and directorates). If personnel from these institutions should participate to a larger degree in developing aquaculture in other countries, extra capacity has to be added on a permanent basis.

In addition, some of the consultancy firms will have personnel with previous experience from working with management and planning on site or project level, while few have experiences from the central (regional or local) management level.

4.2 Environmental aspects and integrated coastal zone management (ICZM)

The pool of competent personnel within environmental planning/ICZM is fairly large in Norway. All the universities and several regional colleges have researchers and PhD students that have been involved in examining various environmental aspects of aquaculture. The same applies to many of the specific research institutions, such as NIVA and Akvaplan-NIVA and a number of consultancy firms. Again, we will find that most have their experiences from Norway, but many of the methods and approaches are generic, and can relatively easily be applied also in other contexts. Environmental Impact Assessment (EIA) is increasingly being used when establishing aquaculture operations, and several of the institutions mentioned above together with IMR have participated. We also find experienced planners in many

Norwegian municipalities and provinces (*kommuner/fylkeskommuner*). However, very few have experiences from developing countries. Many have valuable technical qualifications related to mapping and the use of GPS-systems.

In the Norwegian setting, sea lice and escapes are at present the most pressing challenges. While the use of chemicals is still the primary method to get rid of the lice, new methods such as introducing lice predating species (wrasse and lumpfish) in the net pens are now actively being pursued by several companies. Marine Harvest is also trying out new concepts such as the production of post-smolt (up to 1 kg) in land facilities, before putting the fish out in semi-contained tanks at sea. If successful, this could lead to reduced mortality (at present ca. 20 percent) and no escapes. These examples are just two of many, demonstrating that environmental challenges are being taken seriously, and involve new solutions – most often developed by the companies in close cooperation with research institutions.

4.3 Establishment of brood stocks and genetic improvements

Establishment of brood stock populations and systematic breeding programs to improve biological performance are considered key factors in development of sustainable aquaculture. A program for collection and selection of wild salmon stock initiated by researchers at the Agricultural University of Norway (now the Norwegian University of Life Sciences (*UMB*)) more than 40 years ago, is among the most important reasons for a successful development of the Norwegian salmon industry.[16] From the early 1980s, the family selection programs for salmon and rainbow trout were further developed by the researchers at *Akvaforsk,* and during the 1990s this program was strengthened with new capital from the salmon industry, government institutions and the financial sector. The goal at this point was to invest in facilities and operations that could serve the industry's future demand for the best genetic material. At the same time, other privately financed breeding programs were initiated and developed. The model of an early government support to collect brood stock and initiate breeding programs has also been provided during the early development stages of Atlantic cod farming, which started in the early 2000s in parallel with a rising interest for intensive cod farming. Significant genetic improvements in fish growth, feed conversion, protein and energy retention as well as the more recent development in techniques for production of disease resistant offspring have all been important contributions to the industrial development of Norwegian salmon farming.

Today, commercial and privately owned companies headed by AquaGen and SalmoBreed are the primary contributors of genetic improvements in salmonids. However, the general competence and know-how related to planning, the collection of wild fish and the development of practical breeding programs are transferable to various species and cultural systems, and several Norwegian institutions and private consulting companies are

[16] It should be emphasized that we are talking about selective breeding, a technique originally developed for improving Norwegian livestock. So far, this program has not involved genetically modified organisms (genetic engineering), although research is now being done on developing triploid fish, i.e., fish that cannot breed.

involved. As an example, Akvaforsk Genetic Centre (AGC) has participated in breeding programs in 14 countries involving 13 different species. Other privately operated companies have developed in-house breeding programs on salmon and cod that show significant improvements in biological parameters important to farm economics and to fish welfare. Thus, establishment and early selection programs for brood stock must be considered key competence factors within Norwegian fish farming expertise.[17] The methods and strategies related to establishment of brood stocks and genetic improvements should be of great value for countries developing fish farming.

4.4 Hatchery production of eggs, larvae and fingerlings

Norway is among the few countries that have been able to develop industrial fish farming. In parallel with the rapid development of the salmon industry during the 1980s, researchers at Norwegian institutions and private companies began to work with biological solutions and methodology for larval rearing of marine cold-water species, such as halibut, turbot, cod and species of shellfish. This development focused on medium-sized biological communities (mesocosms systems) to enhance natural plankton blooms to provide sufficient food of high quality for the early life stages of marine species. These systems can be compared to the small-scale extensive systems used in developing countries today. Being only partially able to control the output of larvae and fingerlings from such medium-sized systems, private Norwegian companies decided during the 1990s to focus on intensified and controllable production techniques for marine species. During this period, several Norwegian research institutions worked with the development of protocols for marine fish species (IMR*, Nofima* and *Sintef*) and therefore also gained considerable knowledge into this field, particularly in the area of larval rearing. At the same time, private companies and consultants adapted and modified technology developed for salmonids to marine fish such as Atlantic cod and halibut. During the 2000s, both private companies and Norwegian research groups successfully developed an intensified hatchery technology from brood stock to fingerlings for Atlantic cod. This marine hatchery concept is a further development of the Mediterranean hatchery technology used for sea bass and sea bream in the 1990s. The following areas of expertise in marine hatchery technology are therefore highly relevant for transfer to existing aquaculture and planned hatchery operations in most development countries:

- Development of efficient production systems for fish eggs (brood stock holding tanks, egg collectors and light manipulation programs).
- Development of stable high density live feed cultures for early larval stages of fish (micro algae and rotifers).

[17] Genomar is one of the few companies that have established brood stocks and hatcheries in Asia. Here Norwegian Peace Corps volunteers have been involved in exchanging knowledge and research. The Norwegian Technical University (*NTNU*) has been involved in establishing brood stocks (for cobia) and hatcheries as part of the NUFU program at the University of Nha Trang in Vietnam.

- Early application of high quality micro feeds in combination with the use of specially designed larval tanks to provide high feeding rates, low levels of bacterial load and increased survival of fry.
- Development of protocols for good hygiene, fish disease prevention and fish welfare.
- Application of recirculation technology to improve water quality and to enhance output from hatcheries.

4.5 Formulation of fish feed and application in aquaculture

Starting in the late 1970s with research programs on rainbow trout, Norway has developed a high level of competence within nutrition and feed formulations for application to various species of fish. Norway's fish feed industry has grown in parallel with the salmon production, and the sector is presently dominated by three large transnational fish feed producers (Skretting, Ewos and Biomar).[18] The competence level of these companies concerning ingredients, nutritional composition and feeding strategies is high, but development of feed for new species has not been a prioritized field due to the demand and focus on large volumes. It is important to note that there are large feed companies operating in many regions. An example is Thailand and South East Asia. Here you will find companies such as Charoen Pokphand, Thai Union and Bethagro, offering both shrimp and fish feed. In other regions, as in parts of Africa, there is only very limited production of fish feed.

Presently, government research in nutrition and fish feed formulation in Norway is primarily performed by the research institutions *Nifes* and *Nofima*. IMR has also been conducting programs of applied research within these fields. In addition to these institutions, there are private consultants specializing in feed formulation and nutritional advice to the fish farming industry. Replacement of fishmeal by plant protein is a new and promising trend in feed development, creating opportunities for increased fish production on a global basis. Relevant knowledge in nutrition, feed formulation, feed handling and experimental design are all areas that are relevant topics for aquaculture in developing countries. However, it is important to keep in mind that fish feed of today are global products being produced by few companies investing in large capacity feed plants in several countries, competing for the same raw materials and ingredients. Thus, the feed price and quality is very competitive, and the quality control of ingredients, processing technology and the various production steps have to follow international standards protecting the customer and the consumers. Hence, a locally produced fish feed will seldom become a competitive solution to new aquaculture operations, especially if the country in addition lacks raw materials to be included in new fish feed formulations. Access to feed represents a barrier to aquaculture development in many regions. Hence, securing sufficient feed supplies will be of crucial importance. This could also create a basis for replacing the large-scale, non-sustainable use of "trash fish" as fish feed in many areas.

[18] Marine Harvest is now in the process of setting up its own feed production in Norway.

4.6 Fish farming in cages

Norway's aquaculture production is dominated by cage farming technology. More than one million tons of salmon and trout are presently being produced in open cage systems located along the Norwegian coast. Today's cage farming started from small cages operated manually in sheltered areas, developing gradually into large cage systems located in deeper waters in more exposed areas with a high degree of water exchange. These changes have, in addition to the changes of the cage and mooring system in itself, required considerable development in terms of mechanized equipment to monitor environmental conditions, control feeding and fish biomass, handle fish logistics and to maintain cages, nets and moorings. In this process, valuable competence has been accumulated through operational experience and best practice improvements. Research and development programs run by state institutions (IMR, *Nofima* and the universities) and the private sector (fish farmers, technical suppliers, fish health suppliers) have typically focused on new equipment and technology applied to large scale operations and effects on fish growth, fish survival and general biological performance. Theoretical and practical experiences from fish farming in general and cage operations in particular are the key competence areas in Norway relevant to countries with lakes and/or coastal areas suitable for large-scale cage farming.

In line with the industrial development of Norwegian fish farming, much experience has been gained regarding site selections, successful farm organization, prevention of diseases, logistic processes, etc. These topics are typical areas of regulatory consideration and of relevance to developing countries planning to support new aquaculture industries. Procedures to secure fish welfare and to avoid fish escapes have for instance become very important for sustainable development and growth of the Norwegian fish farming industry. The following areas of expertise related to fish on-growing and cage farm technology are relevant for transfer to existing aquaculture and fish farming operations in several developing countries:

- Evaluation and selection of sites and areas for cage farming
- Implementation of cage farm systems and operational procedures
- Feed evaluation, practical feeding and biomass control in cage farms
- Development of protocols for good hygiene, fish disease prevention and fish welfare
- Logistic systems
- Analysis of the complete value chain
- Regulatory framework for cage farming
- Animal welfare

4.7 Fish health, disease prevention and treatment

Control of infectious diseases in fish farming has proved important in marine and freshwater aquaculture and is important both in extensive and intensive farming systems. Infectious organisms such as virus, bacteria or parasites either occur naturally in the water or can be introduced by transport of fish from infected areas. The infectious organism is specific to the fish species and may vary from one region to another and from continent to continent. The most important strategy to prevent fish diseases is good hygiene and husbandry practices.

During the past thirty years, development and use of vaccines have proved efficient and cost effective strategies to preventing bacterial diseases and to some extent viral diseases in farming of salmon and trout (in Europa and America). Today, vaccines have been developed also for use on other fish species and are used on all continents. Due to problems related to development of antibiotic resistance, vaccination is today the preferred strategy to control bacterial diseases. However, development of vaccines is costly and demands a market, which means that the quantity and/or economic value of the fish produced have to be significant.

In most developing countries, fish vaccines are presently not in common use. For treatment of bacterial and parasitic diseases and for prophylactics, use of medicines, pesticides and chemicals is common practice. This represents a concern related to the development of resistance to treatment, food safety and pollution of the environment.

Recently, the Norwegian pharmaceutical company Pharmaq AS has established research on fish vaccines in Vietnam (Pharmaq Vietnam Ltd), and has received an observation license for the first commercial fish vaccine (for pangasius) in Vietnam. In addition, other Norwegian companies have international activities on fish health and aqua-medicine. Both Pharmaq and MSD Animal Health develop, produce and market vaccines, medicine and immune stimulants for the international fish farming market. Their activities in developing countries are primarily focused on species such as pangasius and tilapia.

The University of Bergen, the University of Tromsø, the Norwegian School of Veterinary Science and the Norwegian Veterinary Institute conduct research on fish health and aqua-medicine; epidemiology, fish diseases, fish immunology, vaccine development, etc. In addition to educating veterinarians, Norway has also developed a special line of education of aqua-medicine biologists (at the Universities of Tromsø and Bergen). Aqua-medicine biologists have five years integrated master training in medicine for fish and aquatic organisms, and they have the same authorization (from the Norwegian Food Safety Authority) for fish diseases as veterinarians. While the majority of these candidates have been working with salmon (in Norway, Canada, the UK or Chile), some have been involved also in the farming of other species and have experiences from working in developing countries.

Several of the institutions mentioned above have also been involved in concrete research and education projects in Asia. Over the last four years, the Institute of Biology at the University of Bergen has been involved in a cooperation program with the Nha Trang University in Vietnam and the Research Institute for Aquaculture No. 3 (RIA 3). In this partnership, the Veterinarian institute of Nha Trang has also been involved together with the Norwegian pharmaceutical company Pharmaq.

Over the years, the bilateral program with RIA No.1/HAU has produced more than 100 candidates. The University in Trondheim (*NTNU*) is probably the institution in Norway with the most candidates produced within fisheries/aquaculture/fish processing as part of bilateral agreements and as participants in the large educational program NUFU.[19] The University of Tromsø (NCFS) and the Norwegian School of Veterinary Science have been involved in a comprehensive cooperation program with India, starting in 2008 and concluding in 2013. This is exclusively a research program funded under the Indian-Norwegian Research Cooperation Agreement, focusing on vaccine development. The fish health part of this funding amounted to 100 million NOK. Five universities in India and five scientific institutions in Norway participate, and Pharmaq and MSD Animal Health are the commercial partners. A possible outcome could be the production of fish vaccines in India.

4.8 Equipment - aquaculture technology

Development of adapted technology has been one of the main driving forces behind the development of Norwegian aquaculture from small-scale enterprises to industrial scale industry with good economic returns. Further development in technological R&D is recognized to be the core competitive advantage of Norwegian aquaculture. Integrating technological possibilities to biology and economic terms will be the global focus for a sustainable development, whether in marine or freshwater aquaculture. Vital topics of competence transferable to global settings in the areas of aquaculture technology are:

- Open ocean farming technology, in exposed areas. Including systems preventing escapes by application of new materials and construction systems.
- Introduction to R&D in closed floating constructions including systems for water treatment and recirculation technology.
- Challenging operations of floating devices; feeding systems loading/unloading operations and underwater control of net pens.
- Automation and modeling: Monitoring and control by remote control systems (ICT).
- Technology and methods for documentation of production volumes and process lines, including systems for traceability/tracking.
- Technology for *Integrated Multitrophic Aquaculture* (IMTA); Sustainable aquaculture of fish, shellfish and macroalgea in combined farms. This could be the future of marine aquaculture, adapting to the need of effective use of limited areas in the coastal zone.

[19] In this case, we are referring to Master as well as PhD education in Norway, occasionally to “sandwich” models, where both the Norwegian university and the recipient country university are responsible for the degree.

- Methods for fish welfare and best practice protocols for operational security systems.
- Handling and processing technology for optimal freshness and quality.

Sustainable aquaculture is based upon specific competence on environmental issues, whether operated in freshwater or in marine areas. Based upon new modeling tools developed in Norway (*Sintef*), it is now possible to evaluate coastal zones intended for aquaculture activities related to discussions of carrying capacity and risk assessments.

Many Norwegian companies participate in this field, supplying technical equipment of all sorts, including complete turnkey farms. Of the most important ones we can mention; Akva-Group, NOFI, Storvik Aqua, and AquaCulture Engineering.

A major strength of applied competence in aquaculture is cooperation through multidisciplinary projects integrating both biology and social aspects of industrial development. A "Scandinavian Model" of "Triple Helix" cooperation between industry, research and development institutions and governmental regulatory bodies could be a sound basis for internationalization.

4.9 Water treatment

Water quality is important for any fish farming operation. Extensive and semi intensive farming in earth ponds, raceways and net pens has to rely upon the quality of the natural water available at the site, and often the only water treatment possible is replacement of oxygen (mechanical aeration). However, the more intensive the production, the more important the control with water quality becomes. In addition to replacement of oxygen, removal of toxic metabolites produced by the fish (carbon dioxide and ammonium), particles, feces and excess feed can also be necessary, as are control and regulation of water temperature (cooling and heating).

Water treatment represents at any level the need for planning, investment in equipment and knowledge and consequently, an operational cost. The most costly alternative is the recirculation system. Any aquaculture operation that depends upon water treatment needs an efficient and reliable setup for water quality surveillance and backup, and risk assessment. Intensive water treatment often demands access to public infrastructure such as electricity, transport and communication, etc. Whenever a fish farm is being planned, the first priority is locating a suitable water source, and any plan should always include an assessment of the water quality and availability. To compensate for bad water quality with water treatment is costly and represents a hazard to the production.

Several Norwegian companies are in the market for water treatment equipment, surveillance and control and have been involved in international activities (AKVA-group ASA, Krüger Kaldnes AS, Sterner Aqua Tech AS). Norway also has companies that deliver consultancy services to the aquaculture industry internationally (*Akvaplan-NIVA*). *Nofima,* *Sintef* and *NIVA* are research institutions involved in water quality and deliver consultancy services related to water quality and water treatment.

Several Norwegian universities have research and offer educational programs on aquaculture that include water quality and water treatment. The most prominent are the University of Tromsø, the University of Bergen, the Norwegian University of Life Sciences, the Norwegian University of Science and Technology and the University of Nordland.

4.10 Value added production

Value added production is not a Norwegian specialty, although we have several aquaculture companies conducting value added production, both in Norway and in other countries where Norwegian firms are engaged (Chile, Canada, Scotland, Ireland, Faroe Islands, Vietnam, Malaysia, Honduras, Belize). Most of the expertise here is connected to the companies, although some research institutions have been actively involved both in the development of new products and the actual production machinery, most notably *Sintef* and *Nofima*. This is seen in an entire range of products and product potentials such as salmon and capelin roe, use of underutilized fish/offal resources, enlarged fillets, and the use of enzymes. The idea of using the whole fish (both demersal and pelagic species) has been at the core of this type of research and product development. This is also the case for any input-production into the aquaculture industry, for instance in the field of feed production, where more efficient production methods and new bases for raw materials (animal plankton like Antarctica krill *Euphausia superba*) are continuously being monitored. Researchers from *Nofima* and the University of Tromsø have for years worked with the testing of consumer preferences, while much marketing expertise is found in the Norwegian Seafood Council.

4.11 Certification and food control

As mentioned earlier, certification is rapidly becoming important also in the aquaculture industry. A number of labels have already been created, but the most important appears now to be the Aquaculture Stewardship Council (ASC). Any certification is dependent upon (independent) certification bodies, and in Norway *Det Norske Veritas* (DNV) has a long tradition of performing certification assessments within different sectors.

Many aquaculture facilities worldwide are already certified, specifically tilapia and pangasius farms in Asia. As for salmon farms in Norway, the certification process is now under way, and WWF Norway reports that the first standards were completed in 2012 and a guide is being prepared. As soon as this is finished, ASC can begin certification programs for salmon. It is believed that within a short time seafood buyers can require that suppliers solely deliver ASC-certified salmon. This process is closely followed by Norwegian agencies and research institutes. Both NOFIMA and the Norwegian Food Safety Authority are involved in the process, as these standards will become central for all aquaculture products in Norway. The ambition on behalf of ASC is within few years to acquire the same status as the Marine Stewardship Council (MSC) in the traditional catch fisheries.

Regarding food *safety procedures*, it should be underlined that there is already close cooperation between the Norwegian Food Safety Authority and NIFES, were the latter conduct sampling and biochemical research, and the former carries out the local and regional controls. In addition to the ordinary inspections carried out throughout the year by the regional offices of the NFSA, any problem or disease outbreak will be followed closely. NFSA is also informing the public about any critical event in Norwegian aquaculture, whether or not such events can have any negative effects on salmon as human food. On NFSA's homepages, there is standard information about negative human effects of sea lice control methods, if salmon exposed to sea lice is safe to eat, and how we can keep our wild salmon healthier by avoiding the spread of Gyrodactulus Salaris. The institutions mentioned above are the national entities responsible for Norway's public response on food safety. There are also independent research institutes in this area that could be mobilized in projects involving seafood safety.

4.12 Training and education

The same institutions as mentioned previously would qualify. All the universities would be prospective partners. The Norwegian University of Life Sciences has for many years been involved in aquaculture training and research, specifically in Tanzania, and has a large network in East Africa based on former students. The same applies to NCFS, University of Tromsø, although most former students from this institution have entered traditional fisheries management. Capacity depends upon whether training should take place in Norway, in the project country or as a joint undertaking ("*sandwich model"*). Established lines of education are found at *UiT, NTNU, UiB and UMB*, while capacity development abroad is more limited, at the moment only Vietnam is conducting regional educational programs related to fisheries and aquaculture. NCFS's experience from working together with the University of Nha Trang (formerly the Fisheries University of Nha Trang) demonstrated that when funds are available, good quality programs could be developed within a relatively short time. However, most Norwegian universities are presently cash strapped, and underfunded programs will not be entered into.

4.13 Aquaculture research

A large number of researchers in a variety of Norwegian institutions are involved in aquaculture research. According to one of the latest assessments (from 2011), more than 700 are involved in aquaculture research in Norway (Nævdal et al. 2012), of which half work as researchers, while the remaining are working as technical and managerial staff. In general, Norwegian aquaculture research is situated all around the country – in Tromsø and Bodø to the north and then in the Trondheim, Bergen, Stavanger, Kristiansand, Oslo and Ås areas. As for aquaculture stations, these can be found in Tromsø, Sunndalsøra, Matre and Austevoll. These are all technically equipped for any type of natural variations (also tropical). In addition, all of the large feed producing companies have their own research stations. For obvious reasons, most of this research is based upon important issues in Norwegian aquaculture, related to salmon, trout, cod, blue mussels, etc., while some researchers also have generic knowledge, applicable to other species in other settings (such as fish health, vaccination, etc.). For most of these researchers, conducting research in developing countries is primarily a question of funding and of personal interest.

4.14 Summary

- As can be seen from the brief review above, competence may be found in a variety of private companies, research and educational institutions and within public management. Not all areas are equally well covered, but in sum the Norwegian competence covers the entire value chain, including also research and education.
- Although much of the competence is developed in relation to the farming of trout and salmon in Norway and other salmon producing countries, important areas represent *generic knowledge* that can be transferred to other species and production systems.
- Producers of aquaculture equipment have already demonstrated that many technical solutions can be adapted to other types of fish farming.
- Engagement of private sector companies is largely dependent upon prospects of profitable investments.
- While the listed institutions and firms may have the required competence, the actual mobilization depends upon two crucial factors*: interest* and *funding*.
- Our interviews with a large number of actors within the sector, combined with more than 30 years' experience with fisheries and aquaculture development, seem to indicate that the interest is present.
- Especially within public management institutions, engagement in other developing countries relies upon funding of extra capacity.
- In general terms, the question of funding is largely a political one, depending upon the strategy to be chosen by Norwegian authorities.
- The Norwegian pool of expertise is fairly large, but still small by international standards. This implies that many experts and consultants have already worked together, thus simplifying the task of using experts from various institutions.

Chapter 5

Recommendation for criteria to be used for prioritization of Norwegian development assistance to aquaculture

The starting point for this report is that the traditional capture fisheries are stagnating and that aquaculture is considered to be an important sector in the future, securing food, employment and contributing to poverty alleviation. Furthermore, that Norway has capacity and competence in this area, primarily gained through the successful development of the salmon sector over the last 40 years. Part of this experience can be used to assist some of the developing countries in their endeavors to create aquaculture as a new sector or to channel existing sectors into more sustainable directions. However, any discussion on criteria to be used for prioritization must be that its development needs are *as defined by the recipient country* that will frame the Norwegian assistance. However, also in development assistance, demand is partly determined by what is offered, meaning that a more active marketing of Norwegian capacity and competence could bring in new actors and new requests from countries that so far have been outside the sphere of typical Norwegian cooperative partners.

5.1 Previous experiences

In spite of recent favorable reviews of Norwegian development assistance in the field of fisheries and fish farming (marine and inland), the general impression is that the Norwegian assistance has been *too widely spread,*[20] with some important exceptions *too limited* to make a major impact, and often including *countries with limited potential for fisheries*, either due to lack of resources or lack of capacity to manage these resources.[21] Earlier discussions related to the use of R/V "Dr. Fr. Nansen" (see Barnes et al. 2002) demonstrate that strategic considerations should encompass where Norwegian support can make the greatest impact, in:

- countries with large marine resources,
- countries that have demonstrated good results (or at least efforts) in managing these resources,
- countries with acute need of improving resource management (resources fished down, due to mismanagement or lack of control), or

[20] This should not overshadow that Norwegian development assistance has been crucial also in important fishing nations, such as Namibia and Vietnam. These countries are also central in the last review of Norwegian development assistance in the field of fisheries (MRAG 2008), which is very positive regarding the results that have been achieved over a relatively short period of time (12 years in the case of Namibia).

[21] At present Norway supports fisheries and aquaculture projects in 18 different countries. In addition, the Norwegian supported Nansen program is involved in 32 African countries.

- countries where fish plays an important part in supplying the population with protein.

During the period of strict priorities regarding poverty orientation and geographical concentration (Sub-Saharan Africa), the recommendations above often conflicted with the actual choice of countries and fisheries to be supported. The great challenge to a larger engagement within aquaculture is to avoid a plethora of small projects, in a large number of countries, where it is difficult to measure any lasting effects afterwards, and where the building of country-specific competence in Norway is weak.

5.2 Strategies

For Norwegian authorities, the issue of private versus public investments in aquaculture is hardly an issue. Private investors look for profitable opportunities in countries with moderate risk levels, that is, with reasonably stable political and economic conditions. Norwegian authorities can assist such investments on a moderate scale, primarily in the first phase, attempting to find out whether proposed projects are viable. In Chile, the only developing country with large-scale Norwegian investments in aquaculture, the investors have primarily managed on their own, without much support from the Norwegian state.[22]

Development assistance in its more traditional form is first of all dependent upon a request from a specific country, asking for Norwegian assistance to a particular sector, in this case; aquaculture. Projects will then be decided based upon a number of factors, where availability of funds and expertise are the most important, combined with the strategic outlook for this particular sector in the specific country. Most often, the overall agreement between the two countries determines which sectors should be included in the development cooperation. Granted that Norwegian funds for aquaculture still will be limited, it is worthwhile to consider where Norway would like to be involved, or more precisely; what the geographical priorities should be.

Norway has a long tradition supporting African countries south of Sahara, and countries such as Tanzania, Mozambique, Zambia, Malawi and Uganda are still among the largest recipients of Norwegian development assistance. However, within aquaculture, most sub-Saharan African countries have shown a weak performance. Even after more than 20 years of development assistance, all African countries (south of Sahara) still do not produce more fish from aquaculture than 0.5 percent of the global production (2008) or the same volume as the salmon producing company Marine Harvest.[23] However, more recently,

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[22] The two main producers, Marine Harvest and Mainstream (Cermaq), are both able to raise their own funding, while Norwegian exporters of equipment may have the benefit of export guarantees through GIEK, the Norwegian institute for guaranteeing export credit. Norfund has previously been involved with Fjord's investments in Chile. (Fjord is now part of Marine Harvest.) When investments started in the mid-1980s, Chile was a developing country, while today it is classified as a middle-income country.

[23] Marine Harvest produced 326,623 tons of salmon and trout in 2008.

countries such as Uganda, Ghana and Nigeria have shown promising growth in aquaculture, although starting from a very low base. The reasons may be many and diversified, but lacking historical traditions for aquaculture and water management[24] appears to be a major stumbling block, compared for example with many Asian nations, where previous experience has been used to establish modern aquaculture. For example, the culture of pangasius in Vietnam starting from scratch in the early 1990, and now producing more than 1 million tons annually. This means that if Norwegian expertise and funds shall be applied in an African setting, it will have to be based upon a broad range of activities and with a long-term perspective, while in the Asian context it is much easier to assist in specific areas, where competence may be weak or missing (as, for example, fish diseases and vaccines). Recent experiences from Vietnam seem to strengthen this perspective, as very moderate investments in aquaculture research have yielded impressive results within a short time.

Hence, when Norwegian embassies with the technical assistance of Norad, are evaluating project proposals, they will do so in very different settings. Most African projects will have to be broad based and long-term, while many Asian projects may be more limited in scope, more in depth and with a shorter time perspective. All important aquaculture nations in Asia would benefit from improved planning and monitoring, with specific attention to improved fish health. Here, the main challenge for Norway and other donors is to assist in setting up a viable management system able to handle the rapidly expanding aquaculture sector. Shortly summarized, in Africa (south of Sahara), the primary challenge is to start aquaculture, while in Asia, the challenge is to channel the present development into a more sustainable direction.

There are at least three dilemmas facing Norwegian development assistance within aquaculture. The first applies to poverty status versus ability to create an aquaculture sector. Within the old regime with priority recipients, there were clear geographical priorities, and not least a concentration on the poorest countries. This binding restriction has gradually been lifted, and development assistance is now more geared (and coordinated) towards the larger policy issues, such as combating climate change (through e.g., forestry projects). This also implies that the previous division between poor and middle-income countries is no longer as clear-cut as before. The dilemma is that several middle-income countries may be better able to handle the type of support that Norway can offer in the aquaculture sector. They have on average a better civil service, a higher education level and more realistic plans for the fisheries and aquaculture sector. This is not to say that Norway should abandon its commitment to poor countries, but continue its (recent) more flexible attitude, where the *strategic possibilities of making an impact in the aquaculture sector will be the focus.*

The second dilemma concerns the actual situation and the possibilities of making an impact. In several Asian countries, both inland and marine aquaculture is so overcrowded that any Norwegian intervention (which in terms of the challenges is bound to be limited) will

[24] This argument is part of a much larger debate, where the Asian mode of production is closely connected to management of freshwater resources, used for the cultivation of rice and other crops, whereas this tradition is nearly absent in Africa (with Egypt as an important exception).

have a minimal impact. A program on, for example, fish diseases will have minimal effects as long as the current system of siting is maintained, with thousands of small farms in very small areas. A request for planning assistance should not be turned down, but any intervention into fish health is wasted as long as the farms are located as they are today.

The third dilemma relates to the mismatch between natural and human resources. Several countries in Africa, Asia and Latin America have considerable potential for both inland and marine aquaculture. They have space, abundant labor and large markets either nationally or regionally. On the other hand, in several of these resource-rich countries, corruption and mismanagement are presently major problems. For obvious reasons, a high level of corruption represents both a political and an economic risk for the potential project.[25]

The preliminary conclusion is that Norway has the competence and capacity to make a difference in the field of aquaculture. Whether this potential is going to be used, depends upon the policies of Norway, and on how projects and programs will be organized. Among researchers and administrators in the Norwegian aquaculture sector, there is a keen interest in participating in the development of aquaculture worldwide, within the confines of Norwegian expertise, primarily oriented towards industrial aquaculture of high value species. As already indicated, part of this expertise is based upon *generic knowledge*, which means that Norwegian expertise may also be used assisting small-scale, extensive aquaculture. There is also great interest in participating among the producers of equipment, feed and vaccines. Among the Norwegian aquaculture companies, the interest is limited, with a few exceptions. These companies have their main strengths in the production of salmon and trout, and so far establishments abroad have mainly been in other salmon producing countries (Chile, Scotland, Canada, the USA, Ireland, and Australia), with the notable exceptions of, e.g., tilapia production in Malaysia and pangasius in Vietnam.

5.3 Recommendations

Development in the field of aquaculture, supported by Norway, can in principle be done through four different mechanisms:

1. Through allocations to multilateral agencies, such as Development Banks, FAO, etc.
2. Through bilateral agreements with specific countries.
3. Through regional programs, often anchored in one particular country.
4. Through limited support to Norwegian companies investing abroad.

Regarding the first option, it should be noted that aquaculture has a weak standing in, e.g., the World Bank, while the Asian Development Bank has been considerably more active in this

[25] In the end, this dilemma can also be formulated as the choice of aquaculture versus other interventions in the same sector. As pointed out by Norad, improved inland fisheries in Africa will probably yield much larger fish production than aquaculture during the next decades.

field. There is also some concern that many of the multilateral agencies are cumbersome to work with, and results are not easily seen. On the other hand, strengthening the multilateral agencies with specific obligations towards aquaculture could be one way of channeling more support to the sector. An organization like FAO, operating as a normative agency, has the potential to assist in capacity building in the areas of planning, policy and legislation. The second option has been used for a number of fishery projects over the years, and Norway as well as Norwegian institutions and consultants in the sector have had reasonably good experiences with such arrangements, where resources are earmarked and channeled to specific projects, normally with a time frame of four years and the possibility of prolonging projects that show good results. In earlier times, there has been a strict limitation on the countries available for such bilateral projects, but more recently this constraint has largely been eliminated, although Norway still has a strong focus on the African countries south of the Sahara. The third option has also been practiced in fisheries projects, most recently in the NOMA-FAME arrangement at the University of Nha Trang in Vietnam, where students from the entire region have participated. Earlier attempts using the same approach can be found in the Oldepesca program, comprising all of the Central American fisheries administrations. The fourth option is available to all Norwegian firms that are interested in investing in aquaculture projects, but the funds set aside are relatively limited, and as previously indicated, Norfund has decided to support other types of projects.

If Norway will use the Norwegian competence in aquaculture to a fuller extent in the future, the strategy would have to consider two different options:

1. Strategic projects, limited in scope, mainly in management including laws and regulations, research and education. Focus on the countries where Norway is firmly established as donor, but with opportunities also for middle-income countries, where it is evident that smaller projects could help in solving particular bottlenecks. Support to multilateral organizations to be channeled principally through FAO, which could involve a large-scale program to support the development of aquaculture in Sub-Saharan countries.[26] This option would be to continue the present policy, with a gradual expansion into aquaculture, based upon specific requests from various countries, without any clear geographical priorities.

2. A larger regional program; 150-200 million NOK (over four years), preferably based in one or a few Asian countries, open to participants from several countries and encompassing several disciplines. While a direct comparison with the "Nansen program" would be misleading, as this program is firmly anchored to the boat, the idea of covering several areas and participants from several countries is the same. This also applies to the marketing of the program, as a large, Norwegian funded aquaculture program aiming at supporting the development of the aquaculture industry, either for export purposes or for local or regional food production (or both). Indirectly, such a

[26] This project is mentioned in the recent white paper on food security, see: http://www.regjeringen.no/upload/LMD/Vedlegg/div/strategi_2013_2015_Matsikkerhet_i_et_klimaperspektiv

program would contribute to the reduction of poverty and enhance food security at the same time. The program could be anchored to one (or a few selected) Asian aquaculture institutions, while on the Norwegian side the expertise would be available through a network of Norwegian companies and universities, possibly coordinated by the CDCF at IMR (Bergen). Such a program could be centered on education at various levels, from technical staff all the way to PhDs for special themes of interest for Asian aquaculture. Education should preferably be organized close to research facilities. Universities such as Nha Trang and Can Tho in Vietnam, Bogor University in Indonesia and Asian Institute of Technology in Thailand could be nodes in a network, but the detailed organization would have to be examined more specifically. The program would concentrate on training, research and education and continue for a relatively long period of time (10-12 years). At the moment, three specific areas seem to be of great importance, where Norwegian competence could make a contribution, both in inland and marine aquaculture:

1) Aquaculture management/legislation

- Policies and legislation support, institutional strengthening
- Securing quality standards related to human health
- Siting and allocation of farms (Integrated Coastal Zone Management)
- Improved operational procedures, securing sustainable use of natural and human resources
- Development of aquaculture plans (on national as well as regional level)

2) Research and development

- Genetic improvement of existing aquaculture species
- Fish health and disease management
- Development of fish vaccines
- Adaptation of cage and net pen solutions
- Start feeding

3) Education/training

- Master and PhD in aquaculture and related disciplines at Norwegian institutions
- Education based on “sandwich” models (shared responsibilities for degrees)
- Shorter courses, in-house training, and study tours
- Institutional twinning arrangements

Even if this program proposal is anchored to Asian institutions, it could also serve African and Latin American countries. First, by making study programs also available for students from these regions. Second, by acting as a pilot project, where experiences from the Asian-based program could serve as a basis for later establishment of such programs in Africa and Central/Latin America.

As demonstrated in chapter 2, making aquaculture an important sector is dependent upon willing entrepreneurs, a robust and transparent management system and a considerable research effort. Norway and Vietnam have shown that impressive results can be obtained within a short period, given the right conditions and the right national priorities. This is precisely why the Norwegian experience attracts interest world-wide among potential aquaculture nations (FAO 2011). From the interviews we have made with various Norwegian actors, we notice great interest in assisting developing nations in their aquaculture endeavors. Even if Norwegian competence is closely related to the farming of salmon and trout in cold waters, much of the knowledge and experiences gained have a generic value, i.e., it can be used under other circumstances, with other types of fish and production systems.

Let us not forget that in spite of impressive growth, Norway still produces only 2% of the aquaculture fish in the world, primarily salmon and trout for the more affluent consumers. However, if Norway should make an impact on aquaculture for food and employment in the developing world, this would have to take place through sector support and investments in these countries. Of the annual development budget, less than 1% is presently designated to fisheries and aquaculture projects. However, within aquaculture there is no reason why ambitions should be limited to 1-2%. Norway has the competence that can make a difference, not only in fisheries but also in aquaculture.

5.4 Checklist

Based upon the considerations above, we would recommend the following guidelines regarding Norwegian support to aquaculture projects (in addition to the regular criteria for Norwegian development assistance):

1. A thorough analysis of the project or program idea in terms of what is meant to be achieved, in terms of priorities (creating an export sector, increase food supplies nationally or combating poverty on local level). The goals may not be in contradiction to each other, but the primary priority will largely determine the layout of the project.
2. An analysis of possible points of intervention; is it one particular bottleneck or is it a question of an integrated approach, requiring input in a number of sub-sectors? If it is a *new* project, a number of issues have to be clarified:
   - Water quality and zoning arrangements
   - Environmental effects
   - Fish health conditions
   - Specific requirements for introduction of alien species
   - Availability of fish feed
   - Availability of seed

- Availability of land
- Availability of water
- Availability of infrastructure/logistics
- Availability of (qualified) manpower
- Availability of markets, domestic, regional and international
- Quality and certification requirements for export

3. An analysis of the relevance of Norwegian expertise; is this an area where Norwegian experts have special competence, or would the project be better served with expertise from other nations/regions?
4. An idea of which institutions (in Norway) have the required expertise, including an assessment of the capacity to deliver services during the entire project period.
5. An analysis of development modes (technology, expert assistance, financial support, technical cooperation, twinning arrangements, training, education, research, etc.).
6. An evaluation of the time horizon – knowing from experience that in order to obtain lasting results at least ten years of involvement appears to be required. The project/program also needs an *exit strategy*, in order for Norway not to be permanently involved.
7. An assessment of the biological sustainability issues, i.e., impacts of the project on the surrounding natural environment (removal of mangroves, pollution, use of toxic substances, introducing new species, etc.).
8. An assessment of the institutional requirements on the partner country's side needed to conduct the project in a sustainable manner. (Does the aquaculture administration have the capacity to deal with the project, to report, to deliver the services required, etc.?)
9. If relevant, a baseline study, assessing the pre-project situation in terms of socio-economic conditions (income level, poverty, education, employment, etc.). Such a baseline study could, if the project/program is to be started, be connected to a continuous monitoring program, possibly through an agreement with a local or national research institution, making later evaluations much simpler.

Literature:

Abila, R.O. and E.G. Jansen 1997: From local to global markets: the fish exporting and fishmeal industries of Lake Victoria – structure, strategies and socio-economic impact in Kenya. IUCN, Nairobi.

Bailey, C. and S. Jentoft 1990: Hard choices in fisheries development. *Marine Policy* 14 (4): 333-344.

Barnes, C. ,P. Degnbol and B. Hersoug 2002: A Study of Visions and Options for the Future Work of the Nansen Programme (2004-2007). Report to Norad. Norad, Oslo.

Bene, C., B. Hersoug, and E. H. Allison 2010: Not by Rent Alone: Analysing the Pro-Poor Functions of Small-Scale Fisheries in Developing Countries. *Development Policy Review* 28:325-358.

Briggs, M., Funge-Smith, S., Subasinghe, R., Phillips, M. 2004: Introductions and movements of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific. FAO Fisheries Technical Paper. No. 476. Rome, FAO.

Brown, B. J., M.E. Hanson, D.M. Liverman and R.W. Merideth 1987: Global Sustainability: Toward Definition. *Environmental Management* 11 (6): 713-719.

Chopin and Robinson 2004: Proceedings of IMTA Workshop.pdf Ebook. http://ebookbrowse.com/chopin-and-robinson-2004-proceedings-of-imta-workshop-march-2004-pdf-d23991512

De Silva, S.S, Subasinghe, R.P., Bartley, D.M., Lowther, A. 2004: Tilapias as alien aquatics in Asia and the Pacific: a review. FAO Fisheries Technical Paper. No. 453. Rome, FAO.

EWOS 2010: Sustainable Salmon Feed: Marine Ingredients. EWOS, Bergen.

FAO 2010: The State of World Fisheries and Aquaculture 2008. FAO Fisheries and Aquaculture Department. FAO, Rome.

FAO 2011: World aquaculture 2010. Fisheries and aquaculture technical paper 500/1.

FAO, Rome.

FAO 2012: The State of World Fisheries and Aquaculture 2010. FAO Fisheries and Aquaculture Department. FAO, Rome.

Fréon, P., Cury, P., Shannon, L. and Roy, C. 2005: Sustainable exploitation of small pelagic fish stocks challenged by environmental and ecosystem changes: A review. *Bulletin of Marine Science,* 76: 385-462.

Hall, S.J., A. Delaporte, M.J. Phillips, M. Beveridge and M. O'Keefe 2011: Blue Frontiers: Managing the Environment Costs of Aquaculture. The WorldFish Center, Penang, Malaysia.

Hargrave, B. T., Duplisea, D. E., Pfeiffer, E., and Wildish, D. J. 1993: Seasonal changes in benthic fluxes of dissolved oxygen and ammonium associated with marine cultured Atlantic salmon. *Marine Ecology Progress Series*, 96: 249–157.

Hasan, M. R. and Halwart, M. (Eds.) 2009: FAO Fisheries and Aquaculture Technical Paper. No. 518. FAO, Rome.

Hersoug, B., S. Jentoft and P. Degnbol (eds.) 2004: Fisheries development. The institutional challenge. Eburon, Delft (the Netherlands).

Hersoug, B. 2005: *Closing the commons. Norwegian fisheries from open access to private property*. Eburon, Delft (the Netherlands).

Holmer, M., Black, K., Duarte, C.M., Marbà, N., Karakassis, I. (Eds.) 2008: *Aquaculture in the Ecosystem*. Springer, Berlin.

Howarth, R.W. and Marino, R. 2006: Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over three decades. *Limnol. Oceanogr*. 5: 364-376.

Hudson, J.J., W.D. Taylor and D.W. Schindler 2000: Phosphate concentration in lakes. *Nature* 406: 54-56.

Jackson, A. 2010a: An industry approach for sustainable feed fisheries. *Aquavision.* Stavanger, International Fishmeal and Fish Oil Organization.

Jackson, A. 2010b: Responsible sourcing of fishmeal for salmon feeds. *Seafood Summit.* Paris, International Fishmeal and Fish oil Organization.

James, D. G. 1995: Marine living resources: Present utilization and future. In Reinertsen, H. and H. Haaland (Eds.) *Sustainable Fish Farming.* Rotterdam, A.A Balkema.

Jansen, E.G. 1997: Rich fisheries, poor fisherfolk: some preliminary observations about the effects of trade and aid in the Lake Victoria fisheries, IUCN, Nairobi.

Jentoft, S. and A. Eide (eds.) 2011: *Povert Mosaics: Realities and Prospects in Small-Scale Fisheries.* Springer, Dordrecht.

Karakassis, I., P. Pitta and M.D. Krom 2005: Contribution of fish farming to the nutrient loading of the Mediterranean. *Scientia Marina* 69(2): 313-321.

Kurien, J. 2004: Fish Trade for the People. Toward Understanding the Relationship between International Fish Trade and Food Security. A Report of the Study on the impacts of international trade in fishery products on food security. FAO, Rome.

MOFI 2000: Sustainable Aquaculture for Poverty Alleviation – SAPA Strategy. Ministry of Fisheries, Vietnam.

MRAG 2008: Evaluation of the Norwegian Cooperation in the Fisheries Sector. Evaluation Report 6/2008 Final. Norad, Oslo.

Nævdal, G., D. Møller, T. Pedersen Berge and E. Hovland 2012: NORSK HAVBRUKSHISTORIE - FORSKNING OG UTVIKLING (FoU). Draft. Fiskerihistorisk museum, Bergen.

Olsen, R. and M. Hasan 2012: Limited supply of fishmeal: Impact on future increases in global aquaculture production. *Trends in Food Science and Technology,* 27: 120-128.

Pihlstrøm, M. 2010: Sustainability of Norwegian salmon farming evaluated on the basis of marine feed resources - An exploratory assessment. Master thesis, the Norwegian College of Fishery Science, University of Tromsø.

Sen, A. 1981: *Poverty and famine*. Clarendon Press, Oxford.

Shepherd, C. J., Pike, I. H. & Barlow, S. M. 2005: Sustainable Feed Resources Of Marine Origin. *European Aquaculture Society Special Publication No. 35:* 59-66.

Tacon, A. G. J. and Metian, M. 2009a: Fishing for aquaculture: Non-food use of small pelagic forage fish – a global perspective. *Reviews in Fisheries Science*, 17(3): 305-317.

Tacon, A. G. J. and Metian, M. 2009b: Fishing for feed or fishing for food: Increasing global competition for small pelagic forage fish. *Ambio* 38: 294-302.

Van Houtte, A. 2001: Establishing Legal, Institutional and Regulatory Framework for Aquaculture Development and Management. http://www.fao.org/docrep/003/AB412E/ab412e05.htm

Weston, D.P. 1990: Quantitative examination of macrobenthic community changes along an organic enrichment gradient. *Marine Ecology Progress Series* Vol. 61: 233-244.

Wetzel, R. G. (ed.): Periphyton of Freshwater Ecosystems. Proceedings of the First International Workshop on Periphyton of Freshwater Ecosystems. Växjö, Sweden, 14-17. September 1982.

Wijkström, U. N. 2009: Fish as feed inputs for aquaculture: practices, sustainability and implications. In Hasan, M. R. and Halwart, M. (Eds.) FAO Fisheries and Aquaculture Technical Paper. No. 518, FAO, Rome.

World Bank. 2007: Changing the Face of the Waters : The Promise and Challenge of Sustainable Aquaculture. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/6908

Annex 1

Terms of reference

Assessment criteria for Norwegian assistance to aquaculture in developing countries

Background

Commercial aquaculture has a great potential in developing countries for generating economic development and reducing food insecurity and poverty, as most of the world's capture fisheries seem to have reached their maximum potential for capture fisheries production. The majority of stocks are fully exploited, so further growth in fish production is likely to come from aquaculture production. According to FAO, world aquaculture has grown strongly during the last 50 years from a production of less than a million tons in the early 1950s to 59.4 million tons by 2004.

World aquaculture is heavily dominated by the Asia-Pacific region, which accounts for 89percent of the production in terms of quantity and 79 percent in terms of value.[27] The region has a long history of aquaculture, but rapid extension began only after 1975. Aquaculture in Africa accounts for merely 1.5 percent of the total production, and the development of this sector has been very slow. Few African countries have experience in industrial scale aquaculture. At the same time, there are numerous areas where there is natural potential for such development.

Purpose of the study

Aquaculture is an important area for developing countries. Norway has developed its own aquaculture industry over the last 40 years and has become an important international player. Norway is experiencing an increasing interest from developing countries seeking assistance to their own aquaculture industry. The purpose of this study is therefore to have a background document for defining useful assessment criteria for Norwegian development assistance to aquaculture with the aim of ensuring a cost-effective use of the available resources. The principal users of the guidelines will be embassy staff with responsibility for development cooperation, as well as staff in the Ministry of Foreign Affairs and Norad.

Scope of work

The study should focus on, but not necessarily be limited to:

1) Assessing the potential for commercial aquaculture in different parts of the developing world, taking into account natural resources, as well as institutional, historical and cultural framework conditions;

2) Discussing the role and importance of the different actors within the aquaculture sector (management authorities, investors, research);

[27] FAO (2010) The State of World Fisheries and Aquaculture

3) Identifying critical factors in the aquaculture sector, such as interventions in the natural environment and environmental impacts of the aquaculture industry, feed and culture fish, employment, food security, hygiene and operational standards, selective breeding to improve the fish for aquaculture conditions, institutional framework, investment climate, limitations to production etc;

4) Discussing the relevance of Norwegian competence in different areas of the aquaculture sector; and

5) Recommendation for criteria to be used for prioritization of Norwegian development assistance to aquaculture.

Reporting

The report shall be submitted as follows:

1. Language: English

2. Length: Maximum 100 pages including executive summary with main conclusions and recommendations, but excluding annexes

3. Format: Electronic version with text in Word (A4-size paper all margins 2.54 cm, Times New Roman 12 cpi font, *inter linea* minimum 15 pt) and original tables in Excel 97 or successive version

Team composition

The assignment will be undertaken by The Norwegian College of Fisheries Science at the University of Tromsø, who will assemble a consultant team comprising two-four members (one of whom should be designated as a team leader). CVs of the team leader and members of the team of consultants should be forwarded to Norad for approval.

Timeframe

Submission of report to Norad by 31 October 2012.

Annex 2

List of people met and interviewed:

Edgar Brun, Head of Section. Norwegian Veterinary Institute, Epidemiology, Oslo.

Roy Dalmo, Researcher and Project Coordinator, the Norwegian College of Fishery Science, Fisheries immunology and vaccine development, University of Tromsø.

Ambekar E. Eknath, Director General. Network of Aquaculture Centres in Asia-Pacific NACA, Thailand.

Rolf Engelsen, Senior Researcher. CDCF/IMR, Bergen.

Elin Ersdal, Investment Director. Norfund, Oslo.

Hallgeir Herikstad, Regional Director Rogaland. Norwegian Food Safety Agency, Stavanger.

Viggo Halseth, Managing Director. Skretting Group, Stavanger.

Jens Christian Holm, Director. Directoratet of Fisheries, Aquaculture and coastal management department.

Morten Høyum, Senior Advisor to IMR, Bergen. Former CEO GENOMAR, Oslo.

Ellen Jean-Hansen, Communication Director. GENOMAR, Oslo.

Harald Jelsa, Export Director. Akva-Group, Stavanger.

Bjørn Tore Lunestad, Senior Scientist. National Institute of Nutrition and Seafood Research Norway, Bergen.

Cato Lyngøy, Company Responsible Technology and Environment. Marine Harvest ASA, Bergen.

Kjell Midling, Senior Scientist. NOFIMA, Tromsø.

Bjørn Myrseth Managing Director. Vitamar AS, Bergen.

Morten Kr. Nordstad, CEO. Pharmaq, Oslo.

Roger Richardsen, Senior Adviser. Sintef, Fisheries and Aquaculture, Tromsø.

Kjell Roland, General Director. Norfund, Oslo.

Einar Wathne Deputy Managing Director, EWOS, Bergen.

Heidrun Wergeland, Professor. Institute of Biology, Immunology, Univ. of Bergen.