JOINT REPORT

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European Commission

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Opportunities and challenges for aquaculture in developing countries

Preparation of this document

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Cover page: A fish farmer looking at the promising floating rice in her pond, Gbotoÿe, District of N'Zérékoré - Guinea (Credit: Marc Oswald).

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Acronyms

AFD	Agence Française de Développement
COM	European Commission
DEVCO	Development and Cooperation
DG MARE	Directorate-General for Maritime Affairs and Fisheries
EATiP	European Aquaculture Technology and Innovation Platform
FAO	Food and Agriculture Organization
FCR	Food Conversion Ratio
GIZ	Gesellschaft für Internationale Zusammenarbeit
HACCP	Hazard Analysis and Critical Control Points
IFFO	The Marine Ingredients Organisation
NGO	Non-governmental Organisation
OECD	Organisation for Economic Co-operation and Development
RTD	Directorate-General for Research and Innovation
SME	Small and Medium-sized Enterprises

1 BACKGROUND AND PURPOSE OF THIS DOCUMENT

The interest in aquaculture projects is growing. Considering the specificities of aquaculture and the potential challenges linked to the development of this sector, the Commission's Directorate-General for International Cooperation and Development (DEVCO), Agence Française de Développement (AFD) and the German International Development Agency (GIZ) commissioned this common reference document for use by colleagues in European Union Delegations (EUDs) and in GIZ/AFD country offices. The purpose of the document is to highlight the opportunities and the challenges of sustainable aquaculture development in developing countries. This reference document should not be considered as a set of guidelines, but rather as a compendium of established concepts and past experiences useful for those interested in developing, funding or managing aquaculture projects. As will become apparent, there are no simple, universal solutions to developing sustainable aquaculture in all its different forms; this document is intended to outline the fundamentals required when considering possible interventions.

2 PAST, CURRENT AND EMERGING TRENDS IN GLOBAL AQUACULTURE

Aquaculture is defined by the UN's Food and Agriculture Organization (FAO[1]) as the '*farming of aquatic organisms including fish, molluscs, 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, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport*'.

2.1 THE INCREASING ROLE OF AQUACULTURE IN GLOBAL SEAFOOD PRODUCTION

2.1.1 Global context

Aquaculture has been around for millennia but only started to contribute significantly to the global food supply and rural livelihoods about 30 years ago. Whereas aquaculture provided just 7% of fish for human consumption in 1974, this share had increased to 26% in 1994 and 39% in 2004 (FAO, 2016). By 2014, global seafood[2] production had increased to 167 million tonnes, almost entirely due to the growth of aquaculture (increasing at 7.7% per annum over 1985–2013), which now at 74 million tonnes represents just under half of total seafood production (see Figure 1 below). While the production of some species such as salmon and shrimp has come from intensive farming, much of this expansion has been due to the wide-scale adoption of aquaculture by smallholders and small and medium-sized enterprises (SMEs). FAO estimates that there are now 18.7 million fish farmers, an increase of 6.1 million from 2000 (FAO, 2016). Aquaculture production is worth around EUR 150 billion, of which around EUR 94 billion is from finfish, EUR 22 billion is from shellfish and EUR 5 billion from seaweeds.

Wild-caught seafood production had also grown, but only by 0.6% per annum (FAO, 2016). According to an FAO analysis, given that many wild fisheries are fully fished (58%) or over-fished (31%), it is evident that aquaculture will play a central role in filling the gap between the increasing demand for seafood and what capture fisheries can provide.

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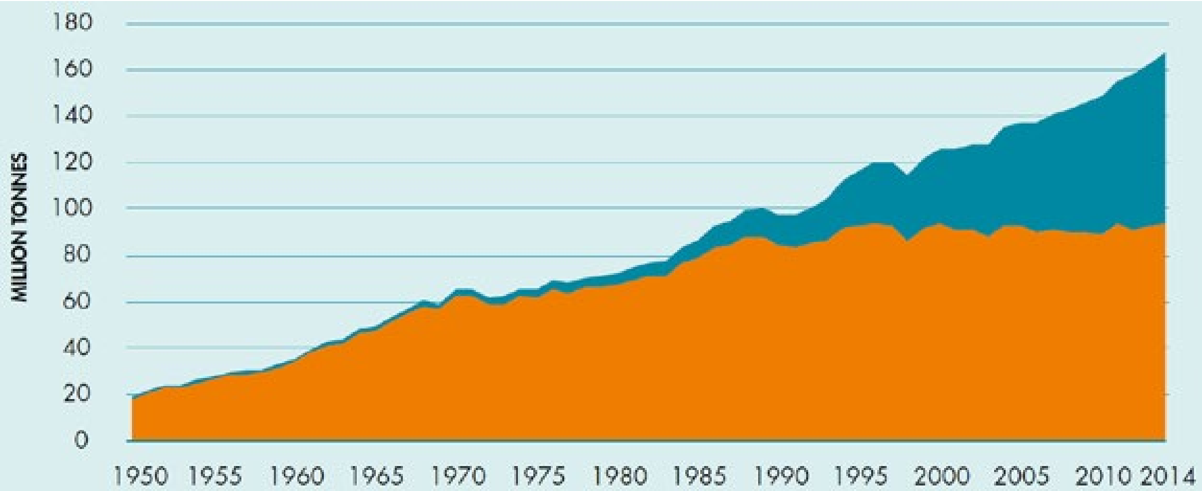
[1] See FAO Aquaculture Glossary at http://www.fao.org/faoterm/collection/aquaculture/en/

[2] The term 'seafood' is commonly accepted to include fish and shellfish, produced in marine and inland waters.

Nevertheless, capture fisheries will remain an important livelihood option and producer of aquatic food in coastal regions and freshwater systems for many countries. Capture fisheries are a major source of fishmeal and fish oil, which are presently essential raw materials for the aquaculture feed industry (see Box 1). While much of this is produced from the industrial reduction of small pelagic fish, low-value bycatch in Asia (often referred to as 'trash fish') is also an excellent source of aquafeeds. Discarded fish and fish processing wastes are increasingly utilised. Substitutes for raw materials for aquafeeds are also being researched with the resulting reduction in the rates of fish meal and oil inclusion.

Figure 1: World capture fisheries (in orange) and aquaculture production (in blue)



Source: FAO (2016)

Box 1: Fishmeal and fish oil from wild fisheries

A recent study (University of Stirling and IFFO, 2016) estimates that 14 million tonnes of whole fish from capture fisheries and 2.7 million tonnes of fish by-products (e.g. through the landing of previously discarded fish and processing waste) are used to produce 4.6 million tonnes of fishmeal and 0.9 million tonnes of fish oil at present. This is likely to grow by 25–30% over the next 10 years, mainly as a result of increased fish by-product availability.

2.1.2 Aquaculture in the European Union

In Europe, aquaculture is mainly dominated by micro and small enterprises; it accounts for about 20% of fish production and directly employs some 80,000 people. While the volume of aquaculture production in the EU has remained relatively constant over the last decade, the value of production has grown by over 40%. Aquaculture is dependent on clean, healthy marine and fresh waters. EU environmental legislation – in particular the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD) and the Regulation concerning use of alien and locally absent species in aquaculture – ensures that these preconditions are met. EU legislation also establishes the high health, consumer protection and environmental sustainability standards with which EU aquaculture activities have to comply. These have cost implications for producers, but this can be turned into a competitive advantage if the consumers' attention is drawn to the quality and sustainability of production. It may also contribute to local acceptability of aquaculture. One of the main challenges that the sector is confronting is linked to consumer image and perception of the sector. Efforts are being made to increase awareness about aquaculture in the EU. This addresses societal concerns based on demand from consumers, non-governmental organisations (NGOs) and retailers for assurances that the food they purchase has been produced to high environmental and social sustainability standards.

The EU Aquaculture Online website[3] is a source of information: it includes the relevant environmental, health, sanitary and other rules, as well as rules governing production for import to the EU market. The website also includes EU national strategies for the development of the sector.

It is worth remembering that the EU is one of the largest global buyers of seafood, importing 1.8 million tonnes of aquaculture products in 2014. Overall the EU sources 56% of its seafood needs from outside of the European region.

2.2 COMPARATIVE ANALYSIS OF AQUACULTURE DEVELOPMENT IN ASIA, AFRICA AND LATIN AMERICA

Aquaculture includes the production of finfish, shellfish (crustaceans and molluscs) and seaweed. Although seaweed production is large in volume, it is mainly used as an industrial raw material rather than directly for human consumption (although the processed products from seaweed such as carrageenan are used in many human food products).

Table 1: Global aquaculture volumes of top 10 species in 2014

All aquatic species			Finfish and shellfish only		
Species	**Volume (t)**	**%**	**Species**	**Volume (t)**	**%**
Eucheuma seaweeds	9,053,044	9	Grass carp	5,537,794	8
Japanese kelp	7,654,586	8	Silver carp	4,967,739	7
Grass carp	5,537,794	5	Cupped oysters	4,378,011	6
Silver carp	4,967,739	5	Common carp	4,159,117	6
Cupped oysters	4,378,011	4	Japanese carpet shell	4,010,703	5
Common carp	4,159,117	4	Nile tilapia	3,670,260	5
Japanese carpet shell	4,010,703	4	White-leg shrimp	3,668,682	5
Gracilaria seaweeds	3,751,396	4	Bighead carp	3,253,143	4
Nile tilapia	3,670,260	4	Catla	2,770,020	4
White-leg shrimp	3,668,682	4	*Carassius* carps	2,767,910	4
Other species	50,287,741	50	Other species	34,648,728	47
Grand total	**101,139,072**	**100**		**73,832,107**	**100**

Source: FAO FishStatJ (2016)

Asia dominates global aquaculture accounting for 92% of all production.[4] China (57 million tonnes) and Indonesia (13 million tonnes) are the main producers, together with India, Vietnam and the Philippines. The main marine species are seaweed and oysters; freshwater species consist mainly of various carps, especially grass, silver and common carps. One should note that the top 12 species produced in Asia are all considered as being 'low-trophic' level organisms. 'Low-trophic' level means that they mainly consume plankton as food, which is important as this is both relatively cheap and 'environmentally friendly', especially compared to higher-trophic level – mostly carnivorous fish – which require high-protein feeds. Much of Asian aquaculture production is integrated with other forms of agriculture, for example through rice/fish systems.

The second largest regional producer in volume terms, the ***Americas,*** produces around 3 million tonnes of aquaculture – just over 3% of the global total. In contrast to Asia, this production is mostly

[3] https://ec.europa.eu/fisheries/cfp/aquaculture_en

[4] Global production figures are taken from the FAO Global *FishStat J* database (Global Aquaculture Production), see http://www.fao.org/fishery/statistics/software/fishstatj/en for installation instructions.

carnivorous species such as white-leg shrimp (21%) and Atlantic salmon (20%). These high-trophic level species require large volumes of protein and fish oil in their feeds, which are mainly derived from fishmeal and fish oil produced from the major capture fisheries for small pelagic species, such as anchovy and jack mackerel in the adjacent eastern Pacific Ocean. Tilapia and mussels are also of importance in this region.

Africa produced around 1.74 million tonnes of aquaculture produce – less than 2% of global production. This is mostly produced in Egypt (*c.* 1.1 million tonnes) with other major producers being Nigeria (313,000 tonnes) and Uganda (111,000 tonnes). Almost half (43.6%) African production is of Nile tilapia. Other freshwater fish species such as African catfish (11.9%) and common carp (10.5%) are also important aquaculture products. Much of the tilapia and catfish are semi-intensively produced, thus requiring additional feeding. There is considerable impetus to develop aquaculture in sub-Saharan Africa, including small-scale cage farming in the large lakes as well as small-scale fish farming integrated into family agriculture systems.

2.3 EMERGING SPECIES, TECHNOLOGIES AND SYSTEMS

Thanks to the current pattern of Asian production, global aquaculture is still dominated by low-trophic level species groups such as seaweeds, carps and bivalves (e.g. oysters). These are mainly produced in extensive systems that need relatively simple equipment and limited husbandry. However, there is a growing demand for higher-trophic level species such as sea bass (both Asian and European varieties), salmonids, some catfish and shrimp from the rapidly expanding middle classes and urbanisation, which is likely to result in a move towards more intensive, high technology farming, including recirculating aquaculture systems. There is also a move to improve the environmental performance of aquaculture through the development of systems such as 'multi-trophic aquaculture' that use low-trophic-level species to utilise the nutrient-rich by-products from high-trophic-level species; for example, farming shellfish in fish farm drainage canals, 'polyculture' (e.g. combining carps with different feeding niches in the same pond) and rice/fish culture (where fish can be farmed in rice paddies, raising overall yields and predating on pests).

Traditionally aquaculture has been at a small scale, addressing family-level subsistence and livelihood needs. This is still much the case in Asia and Africa, although recently there has been an increasing rapid commercialisation of aquaculture. Regarding small-scale production, improvements in husbandry skills, feed and production technologies have allowed higher levels of production. This has been particularly the case in Asia, where there is growing awareness of the downstream value chain and the opportunities it presents. In Africa the commercialisation of small-scale aquaculture has been hampered by various factors, such as poor availability of inputs, limited government support and socioeconomic circumstances (see **Section 6**). Productivity in African aquaculture in general has failed to grow at the same pace as in Asia, and is falling behind demand as human populations increase (WorldFish, 2010).

In the developed countries of Europe, North and South America, commercial aquaculture is dominated by a relatively small number of large companies. This is often with high levels of integration within the value chain; for example, companies have their own processing and value-adding facilities, and focus on a handful of high-value species such as salmon, shrimp, sea bass, sea bream and trout.

3 DIFFERENT FORMS OF AQUACULTURE

Aquaculture can take a number of different forms and operate at various scales. It can vary from subsistence-level 'backyard' fish farming in the family pond to the industrial-scale production of thousands of tonnes from a single site, often destined for overseas markets. Aquaculture systems have mainly been characterised by their productivity, for example, from simple pond farms to high yield re-circulation systems. But in the context of rural development, classification based on a combination of ownership, management, labour and markets is more appropriate (Edwards, 2013). Table 2 looks at various aquaculture systems, categorising them in these terms.

Table 2: Simple classification of aquaculture types

	Commercial	↔		Subsistence-oriented
	Industrial aquaculture	**Small to medium enterprise (SME) aquaculture**	**Small-scale commercial aquaculture**	**Subsistence aquaculture**
FAO typology	Large-scale commercial	SME enterprises	Small-scale aquaculture enterprises	
Production systems	Tanks (flow/re-circulated), cages, pond arrays	Tanks (flow), ponds, cages	Mainly ponds, lagoons, tanks, small cages/pens	Ponds (rain-filled)
Labour	Salaried employees	Mixed, presence of permanent employees	Mainly family members. Activities are integrated into other small-holder farming activities	
Capital	Shared ownership	Family or family groups	Family ownership only	
Management	Financial management with on-farm technical support	Mainly family members, with some professional assistance	Mainly family, possibly with some professional assistance	Family only
Market type	100% sales, including export	Mainly sales, both local and regional	Mixed sales and subsistence	Fully subsistence, little or no sales
Legal status	Operated as a limited company	Limited company or association, independent or none	Sole trader/farmer, or none	Little or no legal status as operators
Access rights to land and water	Legal concession for use	Land owned by the operator or family, or rented	Access to land through customary or family rights	

Source: Adapted from Oswald and Mikolasek, 2016

Industrial aquaculture: Industrial aquaculture is a highly controlled commercial activity. Most companies will be vertically integrated, owning their own broodstock and hatchery, and often post-harvest processing facilities. The animals are stocked at high densities (usually focused on a single species) thus requiring a high level of environmental management and husbandry; a process that is increasingly being automated. Such systems in Asia typically include coastal ponds – normally for shrimp and some finfish production; and the use of sea cages (increasingly in Asia, but also becoming more popular in Africa, especially in the larger lakes). In all intensive aquaculture the animals are fed specialist diets, water quality is often optimised and thus growth rates are high. All this requires considerable investment and ongoing costs (feed, power, labour, maintenance, know-how and managerial capacity, etc.) and thus intensive aquaculture usually focuses on high-value species to ensure a good profit margin. Much of the resulting product is exported from developing countries, although an increasing proportion is being retained to satisfy the increasingly affluent middle classes in countries such as China and India.

An example of industrial fish farming in Africa is the Lake Harvest tilapia cage farm in Zimbabwe. This site on Lake Kariba produces 10,000 tonnes of fish annually, and employs around 600 people. Lake Harvest, which was initially started by the Commonwealth Development Corporation, now also has sites in Zambia and Uganda.

Small to medium enterprise aquaculture**:** SME aquaculture is characterised by its high levels of entrepreneurship. Although unit area productivity may not necessarily be high, SME operations – especially when run in groups or associations – can spread over wide areas and contribute substantially to local fish production. They also tend to be highly entrepreneurial and innovative, taking calculated financial and technical risks. They often look into different opportunities to diversify into new species, production systems or increasing vertical integration, for example, through developing hatcheries. Production systems usually require some investment in water management and environmental control. The juvenile animals are stocked at high densities and there is normally some form of ongoing husbandry, including the fertilisation of ponds (to enhance natural feed production), the use of additional feeds, and regulation of the water levels and quality. The volume produced exceeds the natural carrying capacity of the water body but these enterprises can be successful with a small amount of supplementary artificial feeding and careful management. The most common type of semi-intensive system for finfish are ponds, normally made of earth and sometimes lined with clay, fed by a stream or other water source. This is a common solution in inland areas worldwide. For shellfish, rafts, longlines and trestles are used in inter-tidal and shallow sub-tidal areas. Harvesting is usually organised and the value chain longer than extensive aquaculture, with fish normally being sold in local villages and towns, especially in Africa. In Asia, value chains from semi-intensive aquaculture can be longer and better organised, including local cities.

Botswana has developed a specific 'SME Aquaculture Strategic Plan' focusing on integrated aquaculture/agriculture schemes, and using the entrepreneurial spirit of SMEs to develop new strains and production systems for wider adoption (Davis, 2011).

Small-scale commercial aquaculture: small-scale aquaculture provides an opportunity to diversify small-holder farming activities at the family level. As such, it competes with other crops for land, labour and cash, and the farmer must combine those different crops to get the best income. Integrating fish farming with other forms of agriculture has several positive impacts; for example in better yields, improved (and natural) pest management, more efficient use of water, and spreading cashflow demands and income. At this scale, aquaculture may not be considered an enterprise as such, except when it becomes the main crop (Marc Oswald, pers. comm.). However, it will be an income-generating component of livelihood strategies, thus supporting incomes and increasing resilience to external changes. It usually depends upon there being a dynamic local market for farmed fish.

Rice-fish farming is a small-scale aquaculture activity that is commonly integrated with other farming operations. The income of 2–3 million households in China have significantly increased through rice-fish farming, with income two to four times that of sole crop farming (De Silva and Davy, 2009). Rice-fish farming is also developing in Western Africa (Guinea, Ivory Coast and Liberia).

Subsistence aquaculture**:** subsistence aquaculture is similar to small-scale aquaculture in terms of its integration into other small-holding activities on the family or communal farm, except that it is at a lower scale, is technically simpler and the production is for family consumption only. It is characterised by having little investment, both in terms of infrastructure and ongoing husbandry. Typically, it involves the low density stocking of juvenile fish (usually called fry or fingerlings) in a backyard pond or in community-owned waterbodies. Juveniles may come from a local hatchery, but may also be harvested from the wild and grown-on in captivity. The fish use natural food with no additional feeding. As a result, yields are very low and growth is slow. Harvesting is often *ad hoc*, and consumption is by the household or the immediate local community.

The *Mola Promotion Program* in Bangladesh, which encourages growing these small, vitamin A-rich fish in household ponds, could save 3,000 lives over an 11-year lifetime (Fiedler *et al.*, 2015).

4 WHY CONSIDER AQUACULTURE INTERVENTIONS IN DEVELOPMENT?

On 25 September 2015, countries adopted a set of 17 Sustainable Development Goals (SDGs) with specific targets to be achieved over the next 15 years.[5] These goals cover poverty, hunger, gender equality,[6] economic growth and 'life below water'. While the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for the achievement of the SDGs through recurrent national and sectoral development planning.

The aquaculture value chain – whether it be the primary production stage or the subsequent product supply chain – can contribute to achieving SDGs at both national and regional levels. However, the varied nature of ownership and business models in different forms of aquaculture can have a major influence on which goals might be achieved. These are indicatively summarised in the table below and briefly discussed in the following text.

Table 3: Potential for different aquaculture types to achieve selected SDGs

Aquaculture type	Sustainable Development Goal				
	SDG 1 No poverty	SDG 2 Zero hunger	SDG 5 Gender equality	SDG 8 Decent work and economic growth	SDGs 12, 13, 14 & 15 Environmental sustainability[7]
Subsistence aquaculture	✓ Less family expenditure on food	✓✓✓ Major household protein source	✓✓✓ Equal opportunities at family level	✓✓ Valued work, but limited impact	✓✓✓ Low impact, integrated development
Small-scale commercial aquaculture	✓✓ Generates some income	✓✓✓ Sales at family and local levels	✓✓✓ Equal opportunities at family level	✓✓ Some local economic impact	✓✓✓ Low impact, integrated development
SME aquaculture	✓✓✓ Generates significant income	✓✓ Sales at local level	✓✓ Opportunities skewed towards males	✓✓✓ Dynamic and progressive culture	✓✓ Can have cumulative impacts
Industrial aquaculture	✓ Efficient and increasingly automated	✓ Most produce high value and exported	✓ Opportunities skewed towards males	✓✓ Long value chain, foreign income	✓✓ Can have impacts

Scale: Blank no impact, ✓ some impact, ✓✓ considerable impact, ✓✓✓ major impact

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[5] See http://www.un.org/sustainabledevelopment/

[6] Women can and do play an important role in seafood production, processing and trade.

[7] SDG Goal 12 Responsible consumption and production; 13 Climate action; 14 Life below water; 15 Life on land – see http://www.un.org/sustainabledevelopment/oceans/

Subsistence aquaculture has the potential to contribute to most of the relevant SDGs. This is due to the family level of operations, where work is well distributed, meaningful and empowering. While there is no direct impact on poverty, it does provide a regular supply of high quality protein, sparing income for other food and living expenses. It is also environmentally efficient, especially when integrated into other farming activities. It can make households and communities more resilient to economic or environmental shocks.

Small-scale commercial aquaculture is similar in many ways to subsistence aquaculture in terms of its contribution to the SDGs, but has a greater opportunity to directly contribute to family income, and thus address poverty issues (Béné *et al.*, 2015). This will assist to achieve other SDGs at community level, including good health and education opportunities. It can also generate some jobs, and being local, can be undertaken on a part-time basis by women.

SME aquaculture tends to be fast growing, dynamic and able to diversify into new production schemes and markets. However, expansion and growth may not benefit all, and increasing intensification may introduce environmental and socioeconomic challenges.

Industrial aquaculture can be an important element of economic growth, especially if it generates foreign revenues from exports. It can also produce job opportunities, but these tend to be mostly skilled, and jobs per unit production low. Evidence also shows that commercial aquaculture development and intensification can lead to increased elite capture of resources that negatively affect access and entitlements of the poor (Toufique and Gregory, 2008).

5 AQUACULTURE-RELATED RISKS AND HOW THESE CAN BE MANAGED

As with any livestock industry, there are a number of risks that can impact the viability of aquaculture initiatives. In the past this has significantly affected lending to the sector, but a greater understanding of the risks, and how they can be managed, means aquaculture can be no riskier than, say, poultry farming. This section examines what these risks are and how both external and internal risks can be managed through good project design. Furthermore the likelihood/impact of risks can depend on the type of aquaculture, with integrated systems – either with other aquatic species or with other forms of agriculture – generally being more resilient.

Table 4: Risks associated with aquaculture and management/mitigation approaches

Risks	Likelihood/impact	Management and mitigation approaches
Environmental: habitat damage, eutrophication, pollution, disturbance	Risk heightened by poor siting, farm design and management. Some impacts are reversible, but many are long term.	Use of robust spatial planning (e.g. cumulative and/or strategic environmental impact assessments (EIAs)), as well as site-specific EIAs that ensure good siting, farm design and mitigate potential impacts. Impacts can be reduced by decreasing farm intensity, promoting integrated systems and if necessary, as well as site fallowing. Education, careful management, and regulation are essential to ensure any production is sustainable in the long term.
Climate change impacts: Changes in the altimetric level of water, water quality, vulnerability of certain areas	Risk of loss of activities, jobs and revenues in certain aquaculture areas. Some impacts could be mitigated at local level, but with uncertainty on long-term issues.	Spatial planning and mapping of vulnerable areas (relocation). Use of satellite data for follow up of water level and water quality. Mitigation measures for climate-resilient aquaculture: breeding of species resistant to oxygen deficiency and degradation water quality (e.g. for freshwater fishes, climbing perch, catfish), combination of species with short and adaptable cycle of exploitation, use of local foods, shifts in spawning seasons of the breeding stocks fishes, etc.
Resource use: impact on wild stocks (adults and juveniles), water resources and land	Aquaculture can demand large volumes of fish meal and in some cases, wild juveniles. Can also utilise large areas of land that might have vulnerable dependents.	Responsible sourcing of fishmeal/oil for feeds to reduce upstream impacts. Alternately projects might focus on low-trophic species with lower protein requirements, alternative feed resources, increased feed efficiency (food conversion ratios) through better husbandry. Development of hatcheries can reduce dependence upon wild juveniles. Proactive marine/coastal spatial planning will reduce land/water resource conflicts.
Genetic and biodiversity: introduction of exotic species, inter-breeding and unintentional hybridisation	Genetic 'pollution' from introduced species, as well as their habitat/food competition with native species can have profound negative effects on biodiversity and natural productivity.	Local species should be used where possible, which may require research and development (R&D)/government support to develop viable farming systems and capacity. A strong policy on introduced species, supported by a robust risk assessment, reinforced by import regulations and controls, and strict quarantine facilities is also essential. Strong control and traceability are needed to ensure broodstock lines remain pure, with hatchery and product certification.
Biosecurity: introduction of pathogens, parasites, increased resistance to antimicrobials	Disease epidemics, either from imported animals or from poor management can quickly decimate production. Irresponsible use of antibiotics increases local resistance.	Capacity needs to be established both at government level to ensure that risks are reduced through preventive sectoral management and where necessary, control, as well as at industry level to be precautionary against disease risks and react quickly and responsibly at an early stage of an outbreak. Good disease diagnostics, quarantine and inspection services; disease surveillance, monitoring and reporting; national pathogen lists; legislation and enforcement; contingency planning; can all reduce these risks. Applied research is essential, especially into ways of reducing dependence upon antibiotics.

Risks	Likelihood/impact	Management and mitigation approaches
Food safety: biotoxins, bacteria, viruses, parasites and chemical hazards	Contamination of aquaculture products can impact human health, market confidence and value.	Involves identification of potential hazards, scientific risk assessment, selection and implementation of the best risk management options (e.g. via regulatory food safety measures, Hazard Analysis and Critical Control Points (HACCP) and ongoing monitoring through the value chain) and finally the risk communication to stakeholders.
Social and ethical: poor working conditions, reduced economic opportunities and environmental conditions	Consequences may include brand and reputation damage, heightened regulatory pressure, legal action, consumer boycotts and operational stoppages.	Mitigation must take place throughout the value chain to ensure an equitable distribution of risk and reward. Where extensive contract farming is used (that can create dependence and poverty in some small-scale farmers), strong representation and collective organisation needs to be allowed. Social risks can be reduced through strong and wide stakeholder participation in both project design and implementation, with local in planning, monitoring and evaluation. An initial risk assessment and social risk management measures should be considered where necessary. Local ownership and commitment to project outcomes is essential.

It is apparent that risk mitigation in aquaculture takes place at two levels and by different actors, *by government at the sector level* and by *value chain participants at the site and business level*:

Sector level: the government has a key role in ensuring sustainable development, lowering risks to the sector by a combination of good planning and regulation. Spatial planning is important to reduce conflicts with other activities and to ensure that aquaculture development is proportionate, well-spaced and includes a cumulative assessment of impacts and risks, especially in semi-enclosed spaces such as bays and lakes. The government can also ensure that policy supports both a precautionary and sustainable approach, such as an emphasis on using locally available species where possible, supported by R&D to address the researchable constraints into their viable production, even if this suggests a slower, longer-term development of aquaculture. Governments can also use R&D to proactively identify risks, and to support capacity development in the private sector so these can be mitigated at farm level (see Box 2 below).

Box 2: Risk analysis in aquaculture – experiences from small-scale shrimp farmers in India

The coastal states of India have seen the rapid development of clusters of small-scale shrimp farming, where farmers share water and pond drainage systems, as well as common inputs such as feed and technical assistance. Given the inter-connectedness, the dependence upon one shrimp species and local intensity of production, disease outbreaks were perceived to be a major risk to production and livelihoods. The government's Marine Products Export Development Authority intervened using an epidemiological approach to provide an understanding of white spot disease causation and possible risk management options for reducing the likelihood of shrimp disease outbreaks and low pond productivity. Two key areas of risk mitigation emerged (a) better management practices (BMPs) that are practical farm-level interventions to address the key risk factors; and (b) farmer organisation/self-help groups/clusters to address social and financial risks associated with farming and allow effective dissemination of the BMPs among group members.

Umesh *et al*., 2008

Value chain level: as discussed above, the responsibility for risk assessment and mitigation at the business level lies throughout the value chain. Most businesses understand risk and the consequences for their livelihoods, but not all plan accordingly. For farmers, risk assessment and mitigation starts at the design stage, where robust and considered EIAs are an essential first step in recognising potential risks and ensuring that site selection, farm design and overall approach reduce these to a minimum. The approach is important – does the farm use local or imported seed? Endemic or exotic species? Use of wild or hatchery juveniles? Low or high density stocking? Or home-made feeds or factory formulated feeds? What potential food safety risks are along the value chain and how to prevent/manage them? These decisions need to be based on good information, analysis and planning. This in turn requires a degree of scientific knowledge, informed thinking and common sense which can be reinforced through capacity building and technical support.

The risks to safe, sustainable and economically viable aquaculture are reasonably well known and many have been addressed through international and national measures and the emergence of best practice approaches in the value chain; for example, adoption of HACCP in husbandry and processing activities. Nevertheless, it is important that aquaculture development initiatives assess at an early stage the wide range of technical, financial, environmental and social risks to project participants as well as the wider communities in which they are based. This will ensure that project design reduces and mitigates potential problems from the start, and that project participants are assisted in identifying and addressing emerging issues that might arise while implementation is under way.

6 CONDITIONS FOR SUCCESSFUL AQUACULTURE DEVELOPMENT

Aquaculture is not just a matter of producing fish – it is part of a complex value chain that is itself influenced by a range of environmental, societal and governmental factors that make the difference between a successful or failed initiative. This short section is designed to examine these factors in order to consider some key requirements for sustainable and viable projects. The key points include**:**

- **A strategic aquaculture policy, strategies and development plans at national level**. Food security and economic growth are two main objectives that are commonly promoted for aquaculture. Contrary to popular belief and as explained above, these are somewhat mutually exclusive.[8] Ideally, a national policy sets priorities on which strategies and plans can be developed and supported by donors. When such guidance does not exist, the elaboration of a national policy based on large consultation should be promoted.

- **A good understanding of existing aquaculture and its value chains, together with the opportunities for, and constraints to, development**. The successful production of seafood is just one part of the value chain. In order to succeed long term, aquaculture needs to be profitable and it is essential that reliable markets are secured with a potential value chain that ensures financial viability for all participants. This aspect needs serious consideration during the design phase, as it might influence key design criteria, such as: species selection (reflecting market demand, price and seasonality), system design (which in turn influences input costs, margins and risk), production scheduling, processing and transformation. Value chain analysis is now an established tool for assessing the equity and integrity of value chains and designing interventions to address any issues found.

[8] FAO & Worldfish, 2006. Guiding principles for promoting aquaculture in Africa: benchmarks for sustainable development.

- **Involvement of the private sector, farmers and producer groups**. Aquaculture development should be mainly private sector driven and it is important to find ways to interact with farmers and the other actors of the value chain, possibly through multi-stakeholder groups. Small-scale farmers can, through organisation, gain the advantages of economy of scale in accessing services and markets, which are otherwise limited to large commercial farmers. Farmer groups also improve information exchange and sharing among group members (De Silva and Davy, 2009). The small-scale shrimp farmer groups of India are in a better position today to gain these benefits compared to the situation when they were unorganised (see Box 2 above).

- **Adequate and affordable credit availability and financing instruments:** Aquaculture requires up-front investment in terms of land, infrastructure and inputs (e.g. fingerlings and feed). Insufficient access to capital and cash liquidity is one of the most commonly stated constraints to aquaculture development. It is therefore important that financial structures are in place to provide responsible and reasonably priced lending to project beneficiaries as they expand, especially when the project might be focusing on other elements rather than financing, such as technical development, risk minimisation or capacity building. This is not a critical constraint, as experience shows – so long as aquaculture proponents are able to present a well-considered business case for borrowing, financing is not usually a particular constraint. However, small-scale farmers may lack the credibility and collateral for accessing formal credit, sometimes resulting in unfavourable borrowing from informal sources. It may be a useful project intervention to both develop the capacity of such proponents to prepare business plans as well as to facilitate lending linkages along the value chain.

- **Clear and established rights for access to land tenure and water rights, allied to a transparent, fair and supportive permitting framework**. Successful aquaculture is dependent upon use of a good site that has controlled access to suitable water resources. In the case of marine and coastal farms, this might mean accessing high-value coastal land or sea space in areas that often have considerable alternative value; for example, in tourism or other development. Therefore, securing long-term tenure is essential, with the full support from the government body allocating production rights. On land, ensuring land tenure is equally important, and development of pond farming or other forms of extensive or semi-extensive aquaculture are highly dependent upon a reliable access to suitable water resources. Therefore robust agreements to access and share water need to be established in advance.

- The **existence of a critical mass of public and private sector know-how** at country-level. Essentially, any project must have a core of expertise on which to base intervention activities.

7 POSSIBLE APPROACHES FOR DONOR INTERVENTIONS IN AQUACULTURE

7.1 KEY PRINCIPLES FOR SUSTAINABLE AQUACULTURE DEVELOPMENT

Having understood the main preconditions for sustainable aquaculture development, experience shows that there are a number of key principles to be followed when designing interventions.

Where possible, **align the initiatives with local policy and strategic objectives:** an increasing number of countries have explicit policies for aquaculture development that are supported by plans and measures, often prepared with EU or other funding. It makes evident sense to align new initiatives with these policies and plans, although they should be reviewed in terms of their current relevance. Where such plans are either absent or found wanting, capacity-development support could be considered as a precursor activity, especially when working at sectoral level.

As emphasised in the previous section, **it is essential to build upon the existing local situation and learn from past experience**, both successful and unsuccessful. This might mean using species that already have a viable production base and value chain, with a default preference for local, endemic species where possible. For instance, if there is already the extensive culture of low-trophic species, this should be considered as the starting point. It is also important to recognise the use of efficient systems (such as polyculture),[9] but equally learn from negative experience and events, such as previous disease problems. Another aspect of this is a general principle to **avoid investment in large, expensive infrastructure projects,** especially where they have long-term maintenance costs and support needs. If infrastructure development projects (e.g. hatcheries) are being considered, they should be demand-led and where possible, consider renovating existing facilities rather than new-builds.

Many past aquaculture initiatives have focused on increasing production, but have ignored the downstream markets to their detriment. It is therefore **essential to consider the whole value chain**, even if the initiative then subsequently only focuses on identified weak points.

Communal or collective site development and the giving of gifts should be strongly discouraged, including in small-scale aquaculture projects. It is important that **ownership** is built through both participation and contribution – beneficiaries should be encouraged to contribute to projects, for example through provision of labour and land. And they should be supported to make considered, risk-tested investments, for example through loans and micro-credit. One key point to remember is that **fishermen do not necessarily make good fish farmers**, as the skills sets are very different.

Aquaculture is expanding rapidly in most countries without donor intervention, so one possible approach is, rather than promoting new production per se, is to **build in economic, social and environmental sustainability measures into existing activities**. This could be through capacity building, diversifying production with new species or promoting polyculture, improving business management and planning or focusing on sectoral level governance. Another approach along these lines is adding value to production along the value chain, either through better production practices (e.g. thus allowing eco-labelling/certification), or through post-harvest processing, product development and quality assurance.

Allied to maintaining sustainability, **initiatives should consider an appropriate level of risk and impact assessment** to ensure that social, economic and environmental factors are fully considered in project design, and to reduce the likelihood of any unintended consequences. Proper value chain analysis covering economic, social and environmental aspects can help the development of appropriate evaluation indicators and setting up baseline data collection over the initial phase of project.

Finally, **initiatives should support technical intervention with suitable capacity building**. It is essential that projects build the **long-term human capacity** that is required to ensure sustainable aquaculture development. This needs to be built at multiple levels: for instance with government management and sector support institutions, the private sector (especially at SME level with fish farm and hatchery technicians), community and individuals. Projects should identify capacity-development needs at an early stage in the project cycle, and focus on addressing these as rapidly as possible. In longer-term projects, this can be followed by remote technical assistance through a mentoring approach – this is particularly effective when supporting government sector planning, monitoring and evaluation.

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[9] The culture of more than one species, feeding at different ecological levels, in one system.

Sufficient capacity needs to be established by the time of project completion, both at the vocational level and the academic level, so that local stakeholders are self-sufficient in aquaculture governance, education and research, and extension. In addition to in-country project activities, a core of young university graduates should be selected for post-graduate education, not necessarily just in Europe but also in regional universities that have links with European universities. Upon their return, these graduates should be encouraged to take up positions in education, training and extension at local universities, central and local government departments managing aquaculture, as well as with the private sector.

It is important to build ownership and where possible, transfer project implementation activities to the private sector. Both the public and private sectors have particular roles and responsibilities to play in developing sustainable aquaculture. These are summarised in the table below.

Table 5: Summary of public and private sector responsibilities

Public sector responsibilities	Private sector responsibilities
• Aquaculture policy framework • Legal and management frameworks (tenure rights, licensing, permitting and sector regulation) • Taxation, market (de)regulation and control • Human capacity development • Biosecurity strategies and controls • Strategic environmental assessment and framework for reviewing EIAs • 'Horizon-scanning' research • Climate change adaptation strategies • Facilitating public – private partnerships where appropriate • Support to the private sector	• Sustainable development practices • Input supply and delivery • Development of private extension services • Producer groups • Applied research • On-farm biosecurity • Developing technical and financial modes for diversification • Robust environmental impact assessment of own activities • Ensuring corporate environmental and social responsibility for both employees and customers • Identifying opportunities for public – private partnerships where appropriate • Cooperation with the public sector

7.2 POTENTIAL APPROACHES

This short section examines how aquaculture initiatives might be structured in terms of approach and size. Aquaculture components are notably often part of broader programmes on rural development or food and nutrition security. Nevertheless, ambitious specific aquaculture programmes have been adopted recently in Myanmar (DEVCO/GIZ MYSAP programme[10]) and Cambodia (DEVCO/AFD CAPFISH1 programme[11]).

Generally, in order to gain sufficient traction and impact, **longer-term initiatives of up to five years are favoured**. This allows any precursor activities to be carried out (e.g. establishing or updating sectoral planning frameworks), the phasing and incremental development of technical activities, as well as capacity building and other support processes. It also allows a robust exit strategy to be developed, including a transfer of physical and intellectual ownership as direct donor support comes to an end.

[10] https://eeas.europa.eu/sites/eeas/files/annual-action-programme-2015-myanmar-annex-1_en.pdf
[11] https://ec.europa.eu/europeaid/sites/devco/files/aap-financing-cambodia-annex1-c_2016_8246_en.pdf

That said, **shorter, more focused strategic interventions might be justified in certain circumstances, for instance** addressing critical weaknesses or issues identified during project concept development and design. The use of pilot projects or activities may also be considered, but where possible should be embedded in a longer-term process, such as being a discrete component of a research programme.

Continuing this theme, project design should determine whether a **research component** is appropriate. For short-term projects this might simply be assisting the private sector to work with government and academia to identify and prioritise researchable constraints to aquaculture development and assemble these in a suitable research programme. Longer-term projects might consider a more dedicated research component addressing some of these priorities, such as advancing the domestication of indigenous species, adapting production systems to these strains and environmental conditions and promoting best practices that will mainstream sustainability into the aquaculture sector.

As discussed earlier, **a value-chain approach is always favoured,** ensuring that aquaculture activities are considered as part of a wider network of interdependent businesses. It is also worth considering the value chain in terms of the EU trade context and the market drivers involved.

It is presumed that **most initiatives will be national or sub-national in terms of geographical scope**. If projects are sub-national (e.g. focusing on a certain community area or physical unit), it is often still important to ensure context and institutional support at the wider national level. **In some cases, a regional approach might be considered**, often to address trans-boundary issues (e.g. biosecurity, spatial planning), but also to encourage exchange of good practices, stimulate research and contribute to capacity building. This will normally be embedded in a larger, long-term project so that the critical mass might achieve a real impact.

7.3 PARTNERSHIPS AND COORDINATION

Considering the technicality of aquaculture projects, it seems essential to work with **experienced implementing partners** – these might be development agencies having expertise in this particular field (e.g. AFD and GIZ), research institutes in Europe/the world (e.g. WorldFish), FAO or specialised NGOs (e.g. APDRA). Partnership with development banks can be contemplated to work with the private sector through small grants, loans or public-private partnerships. Within the European Commission, different Directorate-Generals are working on aquaculture issues and might be associated to the development of new projects (i.e. DG MARE, SANTE and RTD).

Partnerships with the EU private sector, academia and research institutions could also be considered, especially with projects that involve the intensification of production, and the introduction of novel techniques and species. The **European Aquaculture Technology and Innovation Platform (EATiP)** can facilitate access to a wide range of EU service providers, and has a specific Working Group tasked with promoting international cooperation activities on aquaculture.

Beyond formal partnerships, good coordination and liaison is also important. This will include alignment in priority goals and approaches for rural development and food security, as well as steps to avoid duplication and the development of complementary activities. There is an informal coordination network in the fields of fisheries and aquaculture which meets annually – the **European Fisheries Development Advisers Network**. The European Commission, AFD and GIZ are members of this network. Informal cooperation can also exist at initiative level, for instance between project proponents, beneficiaries and other stakeholders, both in the project location and further down the value chain. Cooperation will often benefit from being cross-sectoral, such as with Ministries of Finance, Environment and Planning.

As a final note, this sharing of experience shows that there is a wide range of approaches to aquaculture development. It is very apparent that there is no single solution, and that initiatives need to be designed to suit existing circumstances and needs. As always, careful preparation and wide-ranging consultation are key steps to a successful intervention and a long-lasting impact.

APPENDIX A: BIBLIOGRAPHY AND FURTHER READING

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2. USEFUL WEBSITE LINKS

General	**FAO**: http://www.fao.org/fishery/aquaculture/en **WorldFish Centre**: http://www.worldfishcenter.org/content/sustainable-aquaculture World Aquaculture Society: https://www.was.org/ **An Ecosystem Approach to Sustainable Aquaculture** (ECASA): http://www.ecasa.org.uk/
Europe	**EU Aquaculture Online**: https://ec.europa.eu/fisheries/cfp/aquaculture_en **European Aquaculture Technology and Innovation Platform (EATiP):** http://www.eatip.eu/ **European Aquaculture Society (EAS)**: http://www.aquaeas.eu/ **Federation of European Aquaculture Producers** (FEAP): http://www.feap.info/
Asia	**Asia Aquaculture Network**: http://www.asianaquaculturenetwork.com/home.php **Network of Aquaculture Centres in the Asia-Pacific** (NACA): http://www.enaca.org/
Africa	**Interafrican Bureau for Animal Resources: (AU-IBAR):** http://www.au-ibar.org/fish **Sustainable Aquaculture Research Network for Sub-Saharan Africa (SARNISSA)**: http://www.sarnissa.org **APDRA**: http://www.apdra.org/
Americas	Aquaculture North America: http://aquaculturenorthamerica.com/ **Ecuador Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM)** http://www.cenaim.espol.edu.ec/

APPENDIX B: GLOSSARY OF TERMS

Alien species: (non-native, non-indigenous, foreign, exotic, introduced, biological pollutants) are a species that has been transported by human activity, intentional or accidental, into a region where it does not naturally occur.

Aquaculture: the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated.

Best environmental practice: the application of the most appropriate combination of environmental control measures and strategies.

Carrying capacity: the potential maximum production a species or population can maintain in relation to available food resources within an area.

Chemotherapeutants: compounds used by the finfish industry to treat or prevent various diseases.

Codes of Conduct: describe guidance for aquaculture operations in broad terms.

Codes of practice: voluntary codes designed to standardised and improve the management of aquaculture.

Ecosystem approach: an approach that recognises the complexity of ecosystems and the interconnections among component parts.

Eutrophication: natural or artificial nutrient enrichment in a body of water, associated with extensive plankton blooms and subsequent reduction of dissolved oxygen.

Extensive systems: production system characterised by (a) a low degree of control (e.g. of environment, nutrition, predators, competitors, disease agents); (b) low initial costs, low-level technology, and low production efficiency (yielding no more than 500 kg/ha/year); (c) high dependence on local climate and water quality; use of natural waterbodies (e.g. lagoons, bays, embayments) and of natural often unspecified food organisms.

Finfish: fish with fins, that is teleosts, elasmobranches, holocephalids, agnathids and cephalochordates.

Food conversion ratio (FCR): ratio between the dry weight of feed fed and the weight of yield gain. Measure of the efficiency of conversion of feed to fish (e.g. FCR = 2.8 means that 2.8 kg of feed is needed to produce one kilogram of fish live weight).

Intensive systems: system of culture characterised by (a) a production of up to 200 tonnes/ha/year; (b) a high degree of control; (c) high initial costs, high-level technology, and high production efficiency; (d) tendency towards increased independence of local climate and water quality; (e) use of man-made culture systems.

Invasive species: means an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

Polyculture: the rearing of two or more non-competitive species in the same culture unit.

Precautionary principle: the principle that all responsible parties should act prudently to avoid the possibility of irreversible environmental damage in situations where the scientific evidence is inconclusive but the potential damage could be significant.

Semi-intensive system: systems of culture characterised by a production of 2 to 20 tonnes/ha/year, which are dependent largely on natural food, which is augmented by fertilisation or complemented by use of supplementary feed, stocking with hatchery-reared fry, regular use of fertilisers, some water exchange or aeration, often pumped or gravity supplied water and, normally in improved ponds, some enclosures or simple cage systems.

Sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

APPENDIX C: CONTACTS

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More info on BMZ 'Marine Conservation and Sustainable Fisheries – 10-Point Action Programme' (including aquaculture):

https://www.bmz.de/en/publications/type_of_publication/information_flyer/information_brochures/Materialie262_marine_conservation.pdf

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