Global Challenge University Alliance (GCUA) Workshop October 2014, Uppsala, Sweden: Aquaculture

Main Conclusions:

- It is no longer an option to deny the legitimacy of aquaculture as an integral and global part of the human food supply.
- We must focus our efforts on attaining and retaining a social license for aquaculture in both developing and developed nations.
- Aquaculture production must be integrated into all facets of the agro-food industry including public sector regulatory and policy perspectives.
- Governments must be encouraged to provide the same stability and legitimacy to aquaculture as they offer to terrestrial agriculture and fisheries.

Aim: To develop a global network with common research and education agendas and a policy paper addressing the challenges of sustainable intensification of aquaculture by combining new thinking with traditional approaches.

The issue: The FAO estimates that we need to provide 60-100 % more food over the next 40-50 years to meet global demands from a growing and increasingly affluent population. At the same time petroleum based chemicals and energy carriers need to be replaced with bio-based sources. The current agricultural system based on arable land will struggle to meet this challenge. Alternative solutions including a greater reliance on sustainable aquaculture and other non-arable land based systems must be developed if we are to meet the grand challenge of supplying food in a socially and ethically acceptable manner to an increasingly urbanized and affluent global population. Novel circular nutrient production systems which recycle energy and nutrients as well as strong alliances between researchers, farmers and practitioners in developing and developed economies alike are needed if we are to ensure that aquaculture can advance globally and continue to contribute to solving these challenges.

Challenges: There are major technological challenges for sustainable growth and intensification of aquaculture. These include, but are not limited to, improved closed system and off shore system technologies, high quality economically feasible feeds which do not compete with the human food base, and nutrient recapture into circular systems which do not compromise food safety.

Solutions: Aquaculture is a prime target for sustainable intensification because many of the input resources do not compete with other forms of agriculture (e.g. competition for arable land or feed resources). Sustainable growth and intensification can only be achieved through a ‘systems’ approach, taking into account all steps in the food supply chain. By combining tools from socioeconomics as well as life cycle assessment (LCA), biotechnology, food safety and risk assessment, aquaculture has the ability to make a significant contribution to sustainable global-scale environmental, social and economic development. Close communication between industry, policy makers, researchers, regulatory bodies, investors, decision makers, and other stakeholders is crucial for successful identification and implementation of solutions leading to sustainable growth and intensification of aquaculture.

Setting the scene

We foresee that sustainable intensification of aquaculture will develop primarily along two main lines: marine cage systems linked to technical advances in capture fisheries, and circular systems integrated with terrestrial agriculture and urban food supply systems. Aquaculture consists of numerous and diversified production systems, defined by culturing in water. Aquaculture includes a broad range of organisms from animals, plants, macro algae and single cells, with farming systems ranging from extensive, such as shellfish and sea ranching; semi-extensive, such as ponds with natural productivity; semi-closed, such as Recirculating Aquaculture Systems (RAS) for fish; to completely closed systems housed in bio-generators, such as phototrophic micro algae, but increasingly, other heterotrophic microbes.

Fish, shellfish and algae produced through aquaculture activity or caught from wild stocks are increasingly recognized for their nutritional and health promoting qualities and are a primary source of protein and essential nutrients for much of the world's population. Fish is one of the most efficient converters of feed into high quality food and most fish species have the ability to thrive on protein sources of low human interest. Furthermore, aquaculture and aquaculture related products provide income and livelihoods for numerous communities across the world.

World food fish aquaculture production expanded at an average annual rate of 6.2 % in the period 2000–2012 (9.5 % in 1990–2000) from 32.4 million to 66.6 million tons. This optimistic scenario assumes an aquaculture production increase of 58 % by 2022 (4.3 % per year). In 2022, farmed fish will account for 57 % of total fish production for human consumption and 51 % of total fishery production. In that year, total fishery and aquaculture (only including fish and shellfish) production will reach 195 million tons. An increasing world population, growing purchasing power and more people entering the middle class will continue to drive an increasing global demand for seafood over the coming decades.

Future sustainable expansion in aquaculture production capacity will probably occur along two main lines:

(i) Ocean based open systems, with some of it moving increasingly off-shore to escape the constraints of coastal waters. This development is expected to maintain a close integration with marine and fisheries biological and technical development.

(ii) Closed and semi closed inland systems possible to locate close to the consumer with a high land and water efficiency. These systems are already located in close connection to agricultural activity and are expected to be an integrated part of the future agro-ecology system.

Environmental and resource constraints imply that the drivers of future expansion must be based on circular, sustainable production systems instead of having an exclusive focus on short term economic gain. Circular production could be achieved in closed and semi-closed inland systems by direct connection to waste flows of energy and nutrients (especially from the food system). In ocean based open systems, so called blue catch crops will play an important role in circular production. In both cases, feed based on recaptured nutrients which do not compete with the human food base will be an increasingly important issue.

In order to identify key issues and develop a research agenda to support such sustainable intensification of aquaculture, systematic and positive global collaboration between industry, researchers and a multitude of other actors and stakeholders is paramount and needed. Such collaboration is extremely challenging to establish since it involves time-consuming and often painstaking integration of opinions, cultures and deviating interests. Public sector intervention and private sector support are therefore needed.

Successful collaboration is often fostered by creating a neutral arena for cooperation which establishes a platform where system success is the overarching goal and leads to improved gains for all cooperating partners. The Global Challenge University Alliance (GCUA) is an expression of this and has the potential to support and complement such development as identified by FAO.

The FAO has stated that the world should:

> *"Seize the opportunities and address the challenges of aquaculture development"*

The FAO can play a number of roles including leading research, innovation, and development initiatives aimed at enhancing sustainability and productivity of aquaculture and its contribution to the various dimensions of food security and nutrition. These initiatives can be carried out in both small and large scale systems, with due consideration to both food safety and ecosystem integrity. Furthermore, alternative fish feeds must be developed which do not compete with the human food base and contribute to improved fish nutrition and feeding efficiency. Low trophic aquaculture, promotion of herbivorous species, domestication and genetic improvement, integration in agro-ecological models of production at the farm and landscape levels, and improved linkages with the food supply chain all have the potential to contribute to sustainable intensification of aquaculture in the future. The FAO has also highlighted the need to:

> *"Put in place the conditions to develop and implement South-South collaborations to encourage sharing and learning experiences in aquaculture"*

In addition to the issues listed above, work towards food safety must be prioritized considering both the high risk of microbial spoilage of sea food due to its composition and the increasing use of fish feed as a route for recapturing nutrients from food waste. Work addressing a better utilization of the produced fish is also needed at the processing and distribution steps of the food supply chain. Consequently, research topics including different post-harvest losses, infrastructures, cultures, and socioeconomic factors, like employment rights, religion and markets must also be an integrated part of the work.

Key Questions and Research aspects

Aquaculture in future food security and nutrition

Given unlimited access to irrigation, fertilizers and suitable land, the high-tech arable land based agro-food system may be able to meet future global demand for food security in volume and nutrient requirements. However, this will not be the case due to a number of ecosystem limitations and non-food demands for plant materials.

Alternative feed sources which do not compete with the human food base are the fastest and easiest way to relive present pressure on agricultural and fisheries based plant and fish food production. This is vital since nearly 40 % of plant and fishery based food production is presently used for animal feed. Aquaculture production based on nutrients recaptured from feeds based on inputs of low direct value as human food in combination with shellfish/algae aquaculture offers the possibility to produce food without the use of arable land or huge fresh water resources.

Key issues: Issues related to safety, security, food and feed nutritional quality, environmental performance and human and animal ethics must all be addressed.

Research Questions: There are a number of research needs related to biology. Suitable and locally appropriate species of fish and other organisms for cultivation and feed production must be identified. The optimization dilemma of species choice in aquaculture is especially important and the risk posed to wild populations by genetic contamination, disease and farm effluents must be better evaluated. Real alternative feed ingredients which do not compete with land, water and other resources used in food and feed production are especially needed. Comparative studies addressing production efficiency of aquaculture vs. agriculture (e.g. salmon vs. pigs) are needed.

Resource efficient methodologies for breeding programs that meet the aim of present and future food safety and security are needed. Such methodologies will help to ensure that breeding programs can be accessible for more species and applied in less resource rich areas.

Synergies between aquaculture development and livestock breeding and production can be better evaluated. Strategies are needed which stress the importance of conservation of ancestral, wild genes and genotypes for use in present and future breeding.

The growing importance of aquaculture within the global food system demands a better knowledge of the value chains that connect producers to consumers. Tools to evaluate fish quality have been developed and applied at the research level, but a concerted effort must be done to implement them at the entire supply chain, aiming to control waste and regulate pricing as a key to consumer power.

There are many engineering challenges associated with sustainable intensification of aquaculture including improvements in circular systems for plant cultivation with fish or other aquatic organisms. More energy efficient cultivation systems and techniques for recirculation of waste products from urban areas and industries are needed as are technical performance improvements of aquaculture equipment.

Aquaculture in future city food supply system

Global population increase, rapid urbanization and rapid globalization of the world's economy pose growing challenges to urban food supply. Some studies anticipate that global population will level off at 9-10 billion people in the next few decades, but recent estimates increase this figure to 11-12 billion, more than a 50 % increase compared to now. It is projected that over 75 % of the world population will live in cities in the future compared to approximately 50 % at present. Globalization of the food system has been increasingly rapid during the last few decades. For example, Sweden was almost self-sufficient in food after the Second World War, but now imports the main part of its food. Protein from animal sources, such as meat, milk, fish and eggs, account for about 38 % of the global supply while fish account for less than 7 % of the protein consumed by humanity, although it is important to note that these percentages vary considerably among regions and populations.

Rapid growth of cities in all parts of the world has further supported globalization of the food supply system and increasingly moved people away from the sites of food production. This development has been advantageous in some ways, e.g. increased system buffer capacity to weather induced harvest catastrophes and possibilities to large scale food production in fertile areas, but is also problematic. Important challenges to future food supply are (i) food security, (ii) food quality (including safety and nutrition), (iii) environmental performance of food production, and (iv) ethical treatment of workers and ethical handling of animals.

Key issues: Some of the key issues to be addressed include: (i) How can we assure a reasonable degree of local security in food supply also at times with disturbances in the globalized system? (ii) How can we improve food quality – such as nutritional value, taste, absence of infectious matter and chemicals; and also preserve quality? (iii) How can we make food supply more resource efficient, i.e. eco-cycle oriented, minimizing food spillage and waste?, and (iv) How can we improve safety and quality without compromising health of production systems?

Research Questions: Better quantification of energy use and material metabolism so as to decrease energy use per supplied unit of food.

Methods to decrease virgin or raw material use and improve circularity of energy and resource use as well as methods to decrease emissions from food production and supply require further investigation by industry, researchers and other stakeholders as well as greater societal awareness.

Better ways to ensure cost-effective and socially acceptable supplies of protein for human consumption are also needed.

Aquaculture and the human dimension

The latest FAO estimate suggests that in 2010, fish accounted for 17 % of the global population's intake of animal protein and 6.5 % of all protein consumed. Fish is also a major source of livelihoods and income, particularly in developing countries. It is estimated that more than 158 million people in the world depend directly on fish-related activities (fishing, fish farming, processing, and trading). More than 90 % of them are small-scale operators living in developing countries. By 2019, the increasing market for aquaculture is expected to reach 195 billion dollars in annual turnover.

Fish is a particularly nutritious food, rich in numerous micronutrients that are often missing in diets, particularly those of the poor. The presence of essential nutrients (such as iodine, vitamin B12 and D), the long-chain fatty acids (LC-PUFA), eicosapentaenoic (EPA) and docosahexaenoic (DHA) omega-3 fatty acids, protein of high quality and fish's very rich content in iodine, calcium, iron, zinc and vitamin A, is well documented in the literature. It is crucial that these characteristics be preserved or enhanced in farmed fish.

The n-3 HUFA "health bonus" of fish must be supplied by feed. As the use of fish oil is reduced, the "health bonus" may become increasingly dependent on GMO crops as feed sources. This will have profound consequences for the social license of aquaculture and highlights the need for societal consensus about management and alteration of the human food chain.

Aquaculture can make an important contribution to the global food and bio economy system but, like other biological production systems, it may lead to impacts on ecosystems and may affect global flows of energy and resources and thus to the socioeconomic base of whole societies as well as that of individual humans. A large diversity of aquaculture systems exists, both on land and in water, with variable environmental performance and effects. The innovative systems and feed resources must be critically evaluated from a sustainability and socio economic perspective. Preventing competition with feed components that also are suitable for direct human consumption will help aquaculture complement and increase present food production and facilitate shifts between feed resources dictated by supplies and prices. Globally, farmed fish and crustaceans are increasingly dependent on commercial feeds where proteins and lipids are provided by wild fisheries products or increasingly from crops, or crop and livestock by-products. Small pelagic fish should in the future most probably be less available for the aquaculture industry than today, as catches are stagnant, increasingly used for direct human consumption as well as conservation efforts due to growing awareness regarding the status of these stocks and their function in marine food webs and in local small-scale fisheries. Plant and animal based ingredients used to substitute for fishmeal can have environmental and socio-economic implications including e.g. deforestation, high energy demands, release of reactive nitrogen, freshwater depletion, severely affecting the local society and the living conditions of the individual farmer. However, at the present time, they are the only sources where supply can keep pace with demand for aquatic feed sources. Therefore, the development of alternative feed sources capable of large-scale bulk production must be prioritized by all relevant actors.

Given that most feed resources today are sourced globally and the market for sea food parallel that development, a life cycle perspective becomes pivotal in order to reduce, rather than shift, environmental impacts and to secure the economic development also of the individual farmer and local economy.

A number of critical sustainability challenges outside the life cycle analysis (LCA) framework also need to be considered with regard to an expansion of aquaculture, encompassing complex issues associated with sustainability objectives at local, regional, and international scales. Both national/international and large/small-scale aquaculture industry, with the right guidance and participation, could develop into an important industry and provide important contributions to both the local and global seafood market, providing a sustainable source of highly desired food products, employment and economic development.

Public concerns about the environmental impacts of aquaculture and growing demand for seafood products has made market-based initiatives such as certification schemes and consumer recommendation lists increasingly popular and is in fact presently driving global market development. Eco-certification programs for aquaculture and capture fisheries have, however, been criticized for inadequately addressing biophysical demands, global environmental impacts as well as food security and nutrition. Recently it was argued that certification schemes alone may be unable to effectively reduce negative environmental impacts, and that these programs should be complemented by public and private governance. Nonetheless, eco-certification and eco-labelling can be suitable mechanisms for social justice and facilitate the entry of producers representing environmentally and fair trade superior production systems to new markets and to reach retailers, restaurants and consumers.

Key issues: Some of the most important issues to address include human and animal ethics, local versus global markets, private versus public profit balances, the development and dissemination of an appropriate knowledge base and appropriate consideration of gender perspectives.

Research Questions: Some of the research questions to address include inter-country comparisons such as: Life with a successful neighbor; a comparison of aquaculture development between Malaysia or Sweden and their more successful neighbors highlighting the issue of combining natural and cultural resources with the appropriate production system.

Avoiding a repetition of previous mistakes in aquaculture industry development with special reference to animal health and welfare is a key component of sustainable intensification. Merging aquaculture research and social economics is critically needed.

Societal drivers behind successful aquaculture development must be further explored and there is a need to better understand how academic research and training serve and form aquaculture development and food security.

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