Review

Aquaculture and food crisis: opportunities and constraints

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Fish farming, now well known as aquaculture, has been well recognized since the ancient era. The first written document on fish culture was published in China in 475 BC, and the first koi pond was constructed at the Japanese Imperial Palace grounds during 71-130 AD. In recent years, aquaculture has progressively played an important role in the provision of: animal protein and gourmet cuisines, job opportunities, and foreign currency for developing countries. Asian countries produce around 91 percent of the world's total aquaculture production. Among the top ten aquaculture-producing countries, nine are from Asia. The current global population consist of more than 6.5 billion individuals; over one billion of which face hunger problem. In the highly populated Asia-Pacific region with moderately high-productivity, 642 million people are still facing hunger. Being a proficient and potential source of animal protein, aquaculture will play an increasing and important role in solving the world food problem in the future. This paper discusses both the opportunities and constraints in the aquaculture industry, specifically in the Asia-Pacific region, and its possible role in solving the current global food crisis. Strategies including promotion and adoption of traceability and HACCP systems for food safety, and marketing management for aquaculture products are also suggested. It is hoped that traditional administration of aquaculture management for survival, profit, as well as food safety will successfully match sustainability management to meet the urgent global need for food.

Key Words: aquaculture, Asia-Pacific region, food crisis, opportunities, constraints

INTRODUCTION

Asia extends from what is known as the Middle East eastward to Japan, and from the northernmost tip of Russia southward to Indonesia. The region encompasses a huge stretch of land and water that varies from the polar north to the tropical south. Asia is endowed with vast and some of the richest aquatic resources in the world. Many Asian countries border the western Pacific and northern Indian Oceans as well as the adjacent seas which are believed to be the most productive marine habitats in the world. The diversity of aquatic organisms in the region is also unparalleled.

Due to global climate change, domestic or international wars, political crises, increasing food prices, and recent global economic recession, street protests from hungry people have been reported in more than 30 countries, including the most bloody one in Haiti. The current global population is more than 6.5 billion, which include more than one billion hungry people. The highly populated Asia-Pacific region, an area of moderately high-productivity, has the highest hungry population totalling to 642 million people (Figure 1).

In 2008, the price of wheat and corn increased three-folds and the price of rice climbed five-folds, pushing 75 million more people into poverty.[1] It was also pointed out that the high prices were a symptom of a larger problem with regard to the worldwide food web. It is predicted that the grain price in the coming decade will increase by 10 to 20%, mainly due to increasing cost of agricultural products and increased utilization of crops for bio-energy. The high food price is expected to induce an uncontrollable crisis. Food security, defined as "physical and economic access, by all people at all times, to the basic food that they require", is an important issue that will create moderate to serious global problems. Therefore, food security embodies a stable, sustainable, and predictable food supply, equal access for all either by means of production and/or purchasing power, and quality including nutritional adequacy for life functions.[2] In general, the increment of demand is always more than the increment of production, and the increment of hungry people also exceeds the increment of the global population.

THE IMPORTANT ROLE OF AQUACULTURE ON FOOD CRISIS

Since ancient times, fisheries have provided the fundamental needs of many Asians for food at affordable cost, livelihood for families and villages, and even fascinating endeavors such as ornamental fishes. The first systematically written document on fish farming was published by Fan Li in China in 475 BC.[3] The first koi pond was con-

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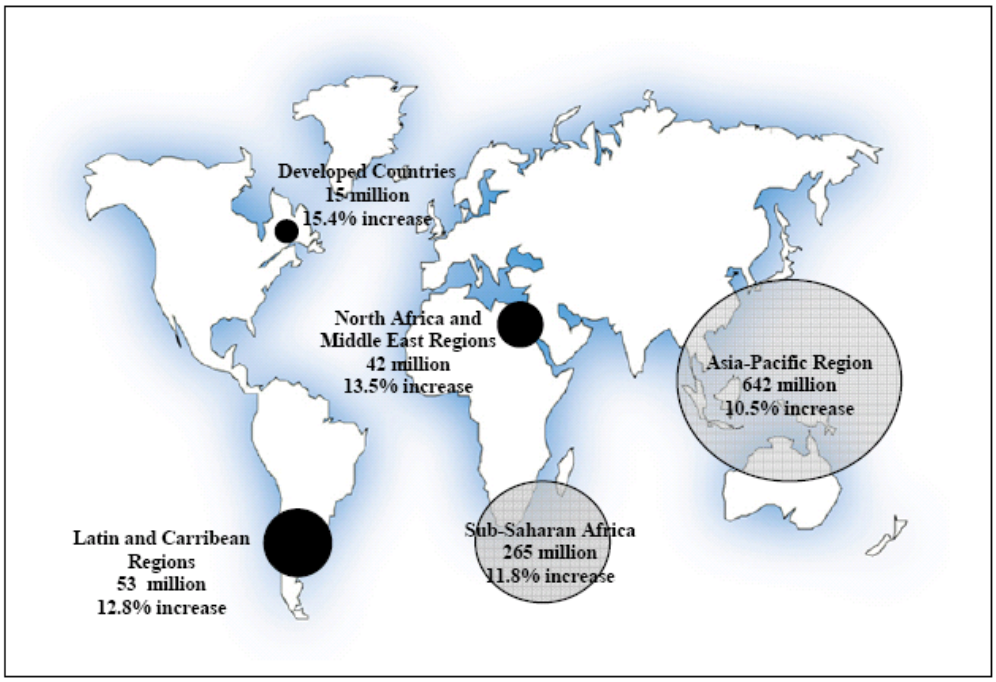

Figure 1. Increase in the numbers of hungry populations around the world from 2008 to 2009.[7]

structed on the Japanese Imperial Palace grounds during 71-130 AD.[4] We are convinced that human beings already had the concept to keep and culture fish in captivity for food many centuries before. Fishes, shellfishes, crustaceans and seaweeds have been important and major items in the diet of Asian people. Their lifestyle is closely associated with fisheries and fish farming and people have special relationships with the use of fish not only for food, but also for social and ceremonial purposes. However, developments in terms of fish farming have been far behind that of crops and livestock industries. There is still enough space and opportunity for aquaculture development, especially in the Asia-Pacific area.

Figures 2 and 3 show global production of major grains and animal proteins.[5] Among the important grains produced, rice, corn and wheat continue to show increasing production trends, while others seem to have reached a plateau. For animal proteins, although there is a slight increment in livestock industries, especially swine and poultry, the aquaculture industry looks promising in supplying the necessary food due to the fact that the ocean covers 71% of earth's surface. Aquatic products are well known for their high contents of high-quality proteins, HUFAs (highly unsaturated fatty acids), phospholipids

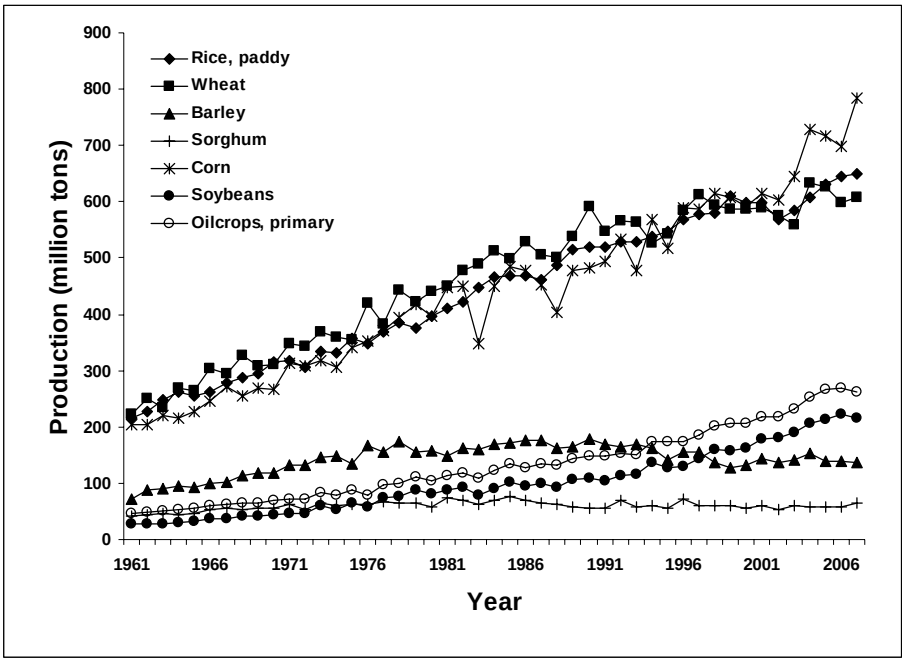

Figure 2. Global production of major grains from 1961 to 2007.[5]

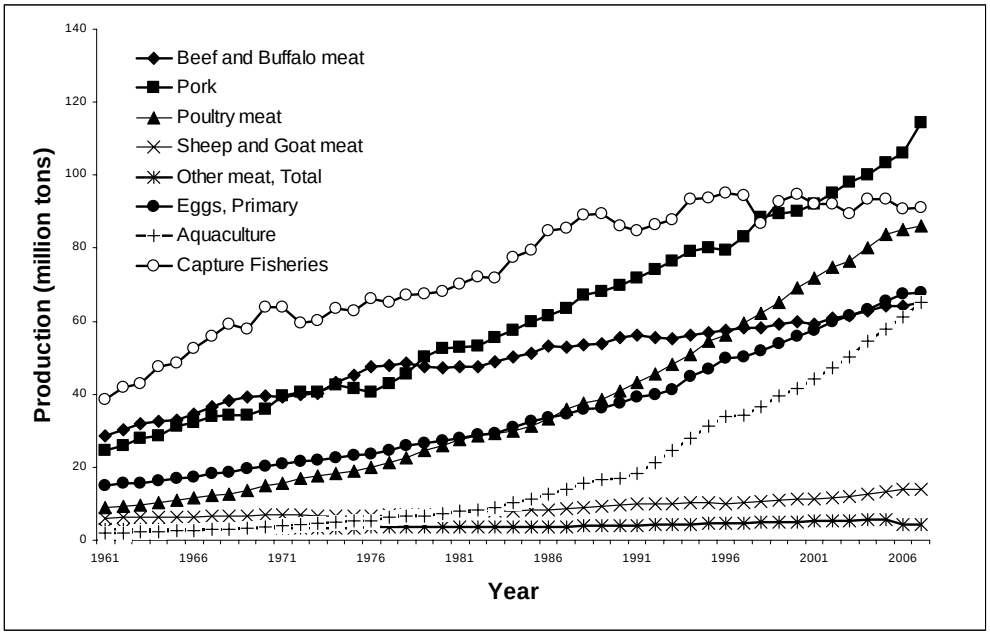

Figure 3. Global production of major animal proteins from 1961 to 2007.[5]

and other nutrients such as calcium, iron, phosphatide, iodide and vitamin A. Jointly, they are essential for physiological processes and are good for humans in terms of infant nutrition, brain and nervous system function, and anti-cancer properties, among others. Since capture fisheries tend to level-off in production, aquaculture becomes the source to meet the insufficient supply of animal protein. The percentage of global aquaculture production in terms of total fishery production was only 3.22 percent in 1950, but quickly increased to 9.72 percent in 1980, 32.02 percent in 2000 and 41.74 percent in 2006, and is expected to reach 50 percent or higher by 2011.[6] Asia-Pacific countries have experienced enormous growth in both exports and imports of aquaculture products.

To fully utilize the resources available to meet future demand of food security and human health, efforts are needed in research and improvement of traditional fish products including fresh, frozen, dried, heat processed, fermented, powdered, comminuted, coated, smoked, baked, and other by-products. For example, development and design of processing equipment to decrease energy consumption, improve quality, conserve vitamins or flavor, and also to protect the environment have taken place. By-products of shrimps and other crustaceans, composed mainly of heads and shells, have been used as good sources of chitin, chitosan and astaxanthin. Aquaculture

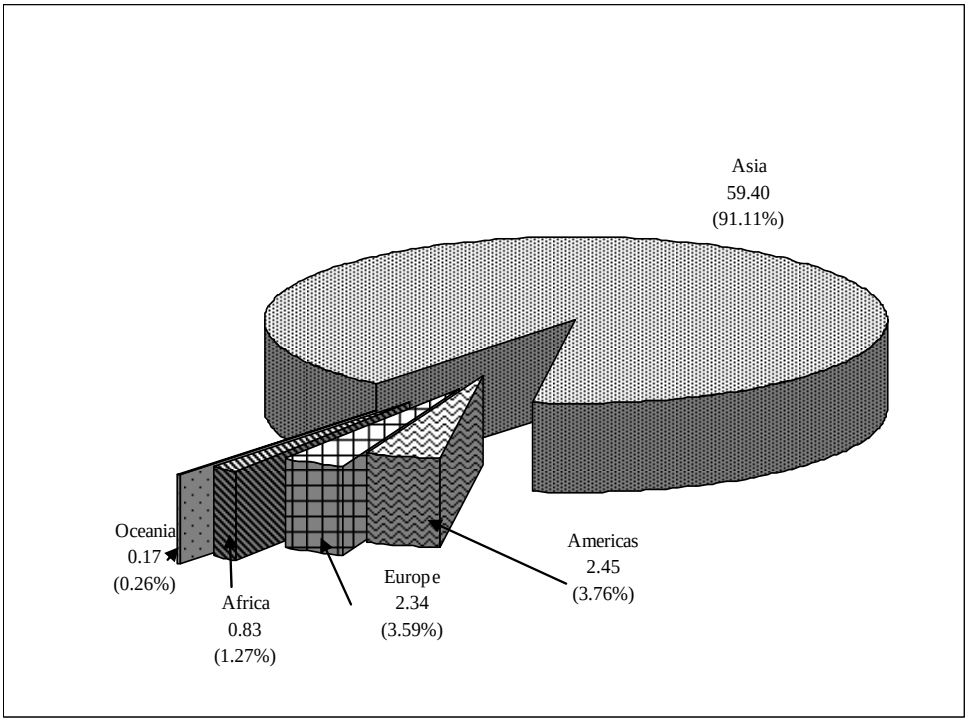

Figure 4. Percentage aquaculture production in Asia and other regions in 2007.[7]

Table 1. Total production of top 20 aquaculture-producing countries in 2007.[7]

Rank	Country	Production (million tons)
1	China	41.17
2	India	3.35
3	Indonesia	3.12
4	Philippines	2.21
5	Vietnam	2.19
6	Korea, Republic of	1.40
7	Thailand	1.39
8	Japan	1.28
9	Bangladesh	0.95
10	Chile	0.85
11	Norway	0.83
12	Egypt	0.64
13	Myanmar	0.60
14	United States of America	0.53
15	Korea, Dem. People's Rep	0.51
16	Taiwan	0.33
17	Brazil	0.29
18	Spain	0.28
19	France	0.24
20	Malaysia	0.21

by-products including fish skins and scales have been used as new sources of collagen.

There are more than 360 aquaculture species in the world, with Asia accounting for 210 species in 2006.[5] The total world aquaculture production has consistently increased since the early 1990s. The top nine aquaculture-producing countries globally are from Asia, which account for 91.11 percent of the world's total aquaculture production (Table 1; Figure 4). It is evident that any decline in Asian aquaculture production will affect the stability of the global seafood supply. Moreover, the percentage of consumed fish from aquaculture has also increased significantly, from 9 percent in 1980 to 44 percent in 2007 and is expected to increase further in the future.[6,8]

Despite the significant increase in aquaculture production, several setbacks have been experienced in overall production, especially in the Asia Pacific region. These are due to an escalating list of problems which the industry will be unable to solve simply by utilizing non-environment friendly culture methods and advanced technology innovation. Such problems include: 1) unresolved and newly emerging disease problems; 2) conflicts between the aquaculture industry and environmentalist regarding adverse effects in the aquatic ecosystems; 3) natural disasters including *El Niño* and *La Niña* phenomena, flooding, drought, desertification and typhoon; 4) movement of investors from one country to another to take advantage of lower tax and cheaper capital for labor and the use of land and water resource; 5) inconsistent and inappropriate management and regulations in many aquaculture-producing countries; and 6) domestic and international marketing problems.

In Taiwan, for example, the once progressive and highly profitable aquaculture industry has been beset by many technical and non-technical problems that greatly affected overall annual production.[9] Thus, it is urgently necessary to find effective and efficient strategies to reduce both internal and external pressures on the aquaculture industry in order to achieve a more sustainable production in the future.

OPPORTUNITIES AND CONSTRAINTS IN AQUACULTURE

Listed below are the opportunities and constraints that the aquaculture industry is facing in its role to significantly contribute to combating the current food crisis and beyond:

Opportunities

1. Understanding the nutritional value of aquatic products resulting in the popularity of consuming aquatic animals and the motivation for the utilization of aquatic plants;
2. Availability of advanced larval rearing and grow-out culture technologies;
3. Versatile production systems including utilization of rice fields, ponds, lakes, rivers, irrigation canals, cages in reservoir, tidal pools, off-shore cages, deep-ocean water, and sea ranching;[10]
4. Sound knowledge of target species' nutritional requirements, compound feed formulations, and feed manufacturing technologies;
5. Progressive study on diagnostic kits for bacterial and viral diseases of aquatic organisms;
6. Promotion of aquaculture zones by the government, and aquaculture farms by private investors;
7. Earning foreign currency through export of aquacultural products;
8. Creation of job opportunities related with aquaculture production including food processing, domestic and international trade, and education in many Asia-Pacific countries;
9. Profit-driven investment by investors from both local- and out of Asia-Pacific areas.

Constraints

1. Land and water competition with other industrial sectors;
2. Insufficient aquaculture engineering for land-based and off-shore aquaculture; lack of knowledge on the adoption of "vertical farm" scheme;[6]
3. The unpopularity of automatic devices for super-intensive aquaculture and post-harvest processing;
4. Problems due to high prevalence of disease outbreaks and natural disasters;
5. State-of-the-art aquaculture is still underemphasized and standardization of operating procedures is not well established;
6. Unrecognized or unfavorable insurance systems; farmers fully dependent on government aids;
7. Improper application of genetic biotechnology for growth promotion and genome conservation;
8. Less efficient management of fish waste and effluents causing downstream environmental degradation;
9. Lack of knowledge in terms of fertilization in open oceans for sustainable off-shore aquaculture;[11]
10. Unbalanced global marketing in terms of profits for Asia-Pacific countries

People from the Asia-Pacific share many common interests in aquaculture and strong potential exists in terms of the development of future scientific exchange. These include nutrition, genetics, larval rearing and grow-out culture techniques, diversification and introduction of new culture species, as well as water pollution and integrated coastal planning. With the opportunities and constraints in aquaculture listed above, more manpower from both governmental- and non-governmental organizations should be involved in research, education, development and extension. In reality though, a good number of those engaged in aquaculture are employed in capital-intensive ventures. Small-scale farmers should also be encouraged to participate in local aquaculture activities. Private sectors in aquaculture using domestic or foreign capital must be developed in similar ways as in agricultural and livestock sectors. Extension programs, technology transfer, turn key projects, and international collaboration should be widespread and strengthened to fulfil the target of sustainable aquaculture. On the other hand, promotion of traceability and HACCP systems for food safety,[12] and efficient marketing management are strongly suggested for regulatory and economic concerns. The traditional administration of aquaculture management for survival, profit as well as food safety were accepted during the progressive phase,[13] but it should move forward to match sustainability management in meeting the urgent global need for food.

CONCLUSION

As an old Chinese proverb says “if you give a man a fish you feed him for a day and if you teach a man how to culture fish, you feed him for a lifetime”. Peter Drucker, an internationally well-known management expert and economist, anticipated that the highest potential industry in the next century is aquaculture but not computer science.[14] Aquaculture is in fact the most stable industry in supplying food in recent decades. The per capita supply amount was 0.7 kg in 1970 and grew to 7.8 kg in 2006. It is believed that a dramatic change is occurring in the aquaculture sector in terms of global food suppliers. Asia has contributed to a steady increase in the world aquaculture production. Current endeavors on the refinement and integration of proper technologies and management such as adoption of regulatory measures, fish health management, and managing external costs in the environment by setting guidelines, pricing mechanisms and deposit-refund schemes, will lead to a more profitable, responsible and environment-friendly aquaculture. However, more well-organized research, development, and extension efforts are needed to solve the relevant problems and improve productivity. Otherwise, aquaculture production will not be able to meet the increasing demand for global aquatic products when capture fisheries and livestock industry can no longer do so. In both the Asia-Pacific and the rest of the world, as well as both the developing and the developed countries, action must be taken to achieve the best outcomes for long-term food supply and security from aquaculture.

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AUTHOR DISCLOSURES

There is no conflict of interest from this review.

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水產養殖與糧食危機：機會與限制

水產養殖被稱為 Aquaculture 是近 40 年來之事。不過在西元前 475 年，中國的范蠡已著有「養魚經」，在西元 71-130 年間，日本皇宮內興建錦鯉池，可見它的重要性。近年來，尤其亞洲國家的水產養殖佔全世界總養殖產量的 91%左右，排行世界前 10 名國家中有 9 名位於亞洲。世界人口已超過六十五億，其中約十億人口面臨飢餓挑戰；而生活在生產力頗高的亞太地區的眾多人口中也有六億四千二百萬人屬於飢餓人口。因此提供重要的蛋白質來源的水產養殖，其今後扮演的角色勢必越來越吃重。本篇就亞太地區之水產養殖作為解決糧食危機問題的機會與限制加以敘述討論。文中倡導養殖履歷制度、採用 HACCP 管控、執行水產養殖產品網路之市場管理，以及落實全面食物安全。至盼水產養殖所追求的生存、利潤、安全，能成功地因應世界急迫的糧食危機，並達永續經營的目標。

關鍵字：水產養殖、亞太地區、糧食危機、機會、限制