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Aquaculture as a food production system: A review

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Abstract
Due to ever increasing human population coupled with the limited availability of space for land-based food production system (such as agriculture, poultry, cattle/goat/pig farming etc), a large number of people across the globe are affected by short and inconsistent supply or unavailability of quality food. A plausible solution of the problem could be enormous utilization of water resources as more than 70% of the earth surface is covered with water. Amongst a variety of food items present in the aquatic system, fishes are considered as the most important group of the organisms suitable for human consumption. However, capture fisheries is showing the signs of almost stagnation for more than a decade. In such circumstances, aquaculture shows a vast scope of expansion. Aquaculture is referred to as "underwater agriculture". Aquaculture is economically more efficient and viable than land based animal farming systems in the sense that fishes are efficient converters of food to flesh and there is more production of fish biomass per unit area. In general, plant products are limiting in one or the other essential amino acids and/or essential fatty acids. However, fishes have well balanced amino acid and fatty acid profile and especially polyunsaturated fatty acids which are present in good quantity. Fish flesh is highly digestible and considered as rich in several minerals and some vitamins. In addition, aquaculture practice generates employment and foreign exchange. Therefore, aquaculture as a food production system shows the potential to provide the quality proteins to ever increasing human population and to combat malnutrition.

Keywords: Aquaculture; Fish; Food production; Malnutrition.

Introduction

The world's population will exceed 8 billion people by 2025 and most of the increase will occur in developing country cities: urban population is expected to rise from 1 billion in 1985 to 4 billion by 2025 and the world food supplies will have to keep pace with the growing demand from the ever-increasing human population. In addition to population growth, income growth also increases the demand for food. Even with modest income growth in developing countries, the demand for food in 2025 will be almost double to the current levels of production. Further, urbanization, in conjunction with income growth, will cause the character of diets to shift away from roots, tubers, and lower quality staple grains to higher quality cereals, such as rice and wheat, animal products, and vegetables (McCalla, 1994). The International Food Policy Research Institute (IFPRI) projections suggest that in developing countries as many as 150 million children-one out of four preschool children-could remain malnourished in 2020 (Pinstrup-Andersen et al., 1997). The challenge facing world agriculture is enormous. The "food gap" the difference between production and demand for food could be more than double in the developing world during the next 25 years, increasing dependence on imports from developed countries. For those countries with sufficient foreign currency reserves, including the rapidly growing Asian countries, this should not be cause for alarm. However, many low-income countries, including most of those in Sub-Saharan Africa, will not be able to generate the necessary foreign exchange to purchase needed food on the world market. Moreover, many poor people within these countries will not be able to afford the food to fully meet their needs. Policymakers, researchers, and others must take proactive steps to minimize uncertainty in the future world food situation in order to achieve food security for all people. In developing countries, policymakers need to ensure that their policies promote broad based economic growth, especially agricultural growth, so their countries can produce enough food to feed themselves or enough income to buy the necessary food on the world market. A world of food-secure people is within our reach, if we take the necessary actions (Pinstrup-Andersen et al., 1997)..

The outlook for the future world food situation will also be significantly influenced by a number of emerging issues. Growing scarcity and inappropriate allocation of water, as well as declining soil fertility in many regions of the world, are beginning to constrain food production. Farm yields in parts of Asia are approaching economically optimum levels, and yield growth rates are slowing. While science, including bioengineering and other modern scientific methods, offers tremendous opportunities for reducing production fluctuations and increasing productivity on small-scale farms in developing countries, little investment is being made in research aimed at these farms. Developments in China and India are of particular interest because policy decisions made, or not made, in these countries are likely to affect not only large populations in these countries themselves, but also the rest of the world. Future food production in Eastern Europe and the former Soviet Union remains uncertain, and Sub-Saharan Africa faces a precarious food security situation. Wide spread conflict and instability are further adding to food insecurity in a number of countries. All of these issues suggest potentially larger fluctuations in food production and prices, and higher associated risks of food insecurity for the world's most vulnerable countries and people. The challenge for policymakers, researchers, and others is how best to minimize these risks to achieve food security for all people (Pinstrup-Andersen et al., 1997).

Developing countries account for 98% of the world's undernourished people. Two-thirds live in just seven countries (Bangladesh, China, the Democratic Republic of the Congo, Ethiopia, India, Indonesia and Pakistan) and over 40% live in China and India alone (FAO, 2010). The number of China's malnourished children will fall by half, while India will experience slower improvement and will remain home to a third of all malnourished children in the developing world (Rosegrant et al., 2001). In India, despite rapid economic growth, the number of hungry people increased by 20 million compared with the baseline period (2003-05), the Food and Agriculture Organization (FAO) observed in its largest briefing paper entitled "Hunger on the Rise". Together, China and India alone account for over 42 percent (231 million in India and 123 million in China) of the chronically hungry people in the developing world (Kanthg, 2008).

Land based food production systems

Less than one-half of the world's land area is suitable for agriculture, including grazing; total arable (crop) land, in use and potential, is estimated to comprise about 3000 million hectares (Lal, 1990). However, nearly all of the world's productive land, flat and with water is already exploited. Most of the unexploited land is too steep, too wet, too dry, or too cold for agriculture (Buringh, 1989). There are difficulties in finding new land that could be exploited for agricultural production. Expansion of cropland would have to come at the expense of forest and rangeland, much of which is essential in its present uses. In Asia, for example, nearly 80% of potentially arable land is now under cultivation (Sehgal et al., 1990). In the 1970s, there was a net annual gain in world cropland of nearly 0.7%. The rate of gain has slowed and, in 1990, the net annual gain was about 0.35% year, largely as a result of deforestation. As much as 70-80% of ongoing deforestation, both tropical and temperate, is associated with the spread of agriculture. The loss of productive soil has occurred as long as crops have been cultivated. Lal and Pierce (1991) in stating this, report that land degradation has now become a major threat to the sustainability of world food supply. This loss arises from soil erosion, salinization, water logging, and urbanization with its associated highway and road construction. Nutrient depletion, over cultivation, overgrazing, acidification, and soil compaction contribute as well. Many of these processes are caused or are aggravated by poor agricultural management practices. Taken together or in various combinations, these factors decrease the productivity of the soil and substantially reduce annual crop yields (McDaniel and Hajek, 1985; Follett and Stewart, 1985; Pimental, 1990), and, more important, will reduce crop productivity in the long term (Troeh et al., 1991). Currently ruminant livestock like cattle and sheep, graze about half of the earth's total land area. In addition, about one-quarter of world cropland is devoted to producing grains and other feed for livestock. About 38% of the world's grain production is now fed to livestock (Durning and Brough, 1992).

Although developing countries will account for most of the increase in global demand for cereals, growth in their demand for cereals is not as rapid as it once was. As population growth slows and people in developing countries diversify their diets away from cereals because of rising prosperity and changing dietary preferences, growth in cereal demand in the developing world is projected to decline from 2.3% a year in 1974-97 to 1.3% a year in 1997-2020. Nevertheless, the absolute increase in the demand for cereals during 1997-2020 is expected to be as large as the increase in demand during the preceding 23 years. Developing countries in Asia, because of their larger and more urbanized populations and rapid economic growth, will account for half of the increase in global demand for cereals, with China alone accounting for one quarter.

The world's appetite for meat is expected to jump enormously. Worldwide, demand for meat is forecast to rise by more than 55% between 1997 and 2020, with most of the increase occurring in developing countries. China alone will account for more than 40% of this increase, compared with India's 4%. Even though demand for meat will double in South Asia, Southeast Asia, and Sub-Saharan Africa, per capita consumption of meat will remain far below levels than in the developed world. This gap suggests that people in these regions will have the potential to consume considerably more meat . Poultry will account for 40% of the global increase in demand for meat to 2020, far higher than the 28% it accounted for in 1997, reflecting a dramatic shift in taste from red meat to chicken. To fuel the explosive rise in demand for meat, farmers will increasingly need to grow cereal crops-particularly maize-for animal feed rather than for direct human consumption. Even though growth in cereal demand is slowing, farmers in developing countries will not be able to keep pace. In most of the developing world, expansion of crop area will be severely limited. In parts of Asia, almost all the suitable land is already under cultivation, cities are encroaching on prime agricultural land, and land degradation is becoming an increasingly serious problem. Sub-Saharan Africa and Latin America have more potential for area expansion. Farmers in Sub-Saharan Africa are projected to bring another 20 million hectares of cereal production under the plow between 1997 and 2020, and farmers in Latin America, 8 million hectares, but the rest of the developing world will account for only another 13 million hectares. Because new agricultural land will be scarce, increasing cereal production will require increasing productivity-that is, getting greater cereal yields from a given hectare of land. However, increases in yields are slowing for all cereals and in nearly all regions. In Sub-Saharan Africa, yields are projected to recover from past stagnation. Nevertheless, yield growth rates in most of the world have been slowing since the early 1980s. In the developed world, the slowdown was primarily a result of policy measures, as North American and European governments drew down cereal stocks and scaled back farm-price support programs in favor of direct payments to farmers. In Eastern Europe and the former Soviet Union economic collapse and subsequent economic reforms further depressed productivity. In developing countries, particularly in Asia, the slowdown in cereal productivity growth stemmed partly from growing water shortages, slowing public investment in crop research and irrigation infrastructure, and heavy use of fertilizers, water, and other inputs (which means that it takes more inputs to sustain yield gains). These forces are expected to further slow growth in cereal yields worldwide from 1.6% a year in 1982-97 to 1.0% a year in 1997-2020. By 2020, the developing countries may be unable to fully meet their cereal demands from their own production (Rosegrant et al., 2001).

Why aquaculture?

For the last several years, we have experienced great advances in scientific and industrial research. This has completely revolutionized our life style. To achieve greater heights in various kinds of developmental programmes, we have never hesitated to interfere and play with norms and process of nature. In the process, to experience the goodness of nature, we started simulating natural mechanisms in artificial conditions. This is becoming warranted in various aspects of life. Moreover, simulating natural mechanisms in artificial conditions requires technological intervention which will further contribute to altering the nature's original plan. All such actions have their long-term impact on human-nature interaction. The nature sometimes responds angrily in various forms such as drought, floods, global warming, unpredictability of weather, low food productivity, declining water level of rivers and groundwater, etc. Also, on one hand, these technological and academic advancements have made several diseases curable and preventable. On the other hand, human interferences have contributed to the alterations in the environmental conditions leading to the development of a variety of new diseases.

Today, in 21st century, when we have been experiencing severe short supply of food items, we need to give it a serious thought that what went wrong that caused this condition. We must introspect and look out for the alternative sustainable options. We need to carry out all kinds of developmental activities which have compatibility to nature's plans. At the same time, we must explore the means and ways to eradicate hunger and malnutrition from the face of the earth. Death of human beings due to hunger and/or malnutrition, even in the 21st century, is a tight slap on the face of modern scientific/social/economic developments. To make it worse, our country, India has figured prominently in this category in the world scenario.

Earth's surface is covered largely (>2/3rd) by water that means we have limited land available for all kinds of activities such as housing, agricultural (food grains) production, industrial development etc. With ever increasing human population coupled with plateauing of agricultural production and shrinking area available for agricultural or land based animal production, we are bound to explore the potential of food production in the aquatic systems. Irrational exploitation of our natural resources (without caring for recruitment and other management aspects), we now have reached to such a point that there are several species which have been overexploited to such an extent that they have either became extinct or endangered or threatened. So far, management programmes of our natural resources, in practice, were focusing mainly to develop means and ways to fully or overexploit the resources so as there is growth in the production figures. We cared very little for the sustainability and feasibility of production from natural resources. Even today, we still do not have all the required basic and precise baseline biological data which can be utilized to frame and implement meaningful guidelines to effectively and efficiently manage our natural resources.

Aquatic production is predominated by fishes but we have been experiencing almost stagnation in the production from natural resources (some reasons have been discussed above). Therefore, there appear two broad options:

(i) To develop and implement effective and efficient management policies for our natural resources.

(ii) To further supplement food production, we must also exploit huge underexploited/unexploited aquatic resources of numerous kinds (be it freshwater / brackish water / seawater / sewage water, etc) for aquaculture.

If there is water, no matter what type, then there are some fishes which can be grown in that particular water body. Aquaculture is the fastest growing food production system worldwide. In the times when majority of the other food production systems are showing decline or almost stagnation in production, aquaculture has been growing at a rate of approximately 9 percent per annum since 1985.

It is now widely recognized that the world's aquatic resources are limited. More than 70% of the global fisheries have already been exploited to the point of extinction or have been exploited beyond capacity. Important transcontinental fish stocks could also collapse before the year 2050 threatening one of the main food sources of more than a billion people on this planet. While the global capture fisheries have been stagnant for nearly a decade, per capita consumption has been increasing each year (Eknath and Jena, 2008).

Although global landings from inland fisheries have grown continuously, there are few examples of collapsing fisheries, and a number of fish stocks, especially in Latin America, remain lightly exploited. Thus, adopting a precautionary approach, the fisheries could be developed further. Results from five case studies of river and lake fisheries show that inland fisheries are highly complex and that, where ecosystem processes remain largely undisturbed, stock dynamics are basically controlled by environmental processes and factors external to the fisheries, such as natural fluctuations in climate, flood patterns, and variations in nutrient inputs (whether natural or resulting from pollution). However, anthropogenic ecosystem impacts in the form of species introductions, pollution, habitat fragmentation and changes in the flood cycle can reduce the resilience of fish stocks to fishing pressure. Catches in the western central Pacific and in the western Indian Ocean have shown an increasing trend. In contrast, capture production decreased by more than 10% after 2000 in both the western and eastern central areas of the Atlantic Ocean, although they are quite different in terms of the main fishery resources and type of fishing. In the eastern Indian Ocean, total catches in 2006 rebounded after the decrease in 2005 caused by the destructive effects of the tsunami that affected parts of this region in December 2004. About 52% of stocks were fully exploited and, therefore, producing catches that were at or close to their maximum sustainable limits with no room for further expansion. Only about 20% of stocks were moderately exploited or underexploited with perhaps a possibility of producing more. Most of the stocks of the top ten species, which together account for about 30% of world marine capture fisheries production in terms of quantity, are fully exploited or overexploited. The areas showing the highest proportions of fully exploited stocks are the northeast Atlantic, the western Indian Ocean and the northwest Pacific. Overall, 80% of the world fish stocks for which assessment information is available are reported as fully exploited or overexploited and thus, requiring effective and precautionary management (SOFIA, 2009).

Fish has been a major commodity in trade for more than thousand years and seafood has significantly influenced the living conditions of coastal people all over the world. Fisheries contribute more than any other animal production activity to protein intake in most of the developing regions of the world. With limitations in land-based food supply and the Malthusian fear becoming real, man has turned more seriously to water-based production systems, mainly to meet the increasing demand of food/proteins-deficit to sustain the exploding global population. While it was easier harvesting wild fish stocks than culturing fish, it has come to a stage that the production through capture fisheries cannot now be increased further. The global annual production has reached a plateau of 85-90 million tonnes, in the last decade. The collapse of fisheries in many regions shows danger plainly. It is therefore the right strategy to concentrate on aquaculture to increase farmed fish production, which has been achieved successfully as evident from the statistics (Kutty, 1999).

Role of aquaculture in global food supply

Whether captured or cultured, fish plays an important role in human nutrition and global food supply, particularly in the diets of the poor and needy as a source of much needed essential dietary nutrients. Food fish currently represents the major source of animal protein (contributing more than 25% of the total animal protein supply) for about 1.25 thousand million people within 39 countries worldwide, including 19 Sub-Saharan countries. Despite importance of food fish in Africa, the Sub-Saharan region is the only region of the world where per capita consumption of food fish has fallen (Tacon et al., 2010). Fish contain high amounts of protein with balanced amino acid profile, and are rich in certain vitamins and minerals. They also contain polyunsaturated fatty acids which are required in the development of the brain, and provide energy-dense fats for infants who may be unable to derive enough energy from a predominantly cereal-based diet (Edwards, 1997).

Capture fisheries and aquaculture supplied the world with about 110 million tonnes of food fish in 2006, providing an apparent per capita supply of 16.7 kg (live weight equivalent), which is among the highest on record (Table 1).

Table 1. World fisheries and aquaculture production.

	2002	2003	2004	2005	2006
Production					
Inland					
Capture	8.7	9.0	8.9	9.7	10.1
Aquaculture	24.0	25.5	27.8	29.6	31.6
Total Inland	32.7	34.4	36.7	39.3	41.7
Marine					
Capture	84.5	81.5	85.7	84.5	81.9
Aquaculture	16.4	17.2	18.1	18.9	20.1
Total Marine	100.9	98.7	103.8	103.4	102.0
Total Capture	93.2	90.5	94.6	94.2	92.0
Total Aquaculture	40.4	42.7	45.9	48.5	51.7
Total World Fisheries	133.6	133.2	140.5	142.7	143.6

Source: SOFIA, 2009.

Global capture fisheries production in 2006 was about 92 million tonnes, comprising about 82 million tonnes from marine waters and a record 10 million tonnes from inland waters. Accounting for more than 10 million tonnes in 2006, inland fisheries contributed 11% of global capture fisheries production and landings from inland waters remain essential and irreplaceable elements in the diets of both rural and urban people in many parts of the world, especially in developing countries.

Oceans of the world are currently at maximum sustainable yield. Since the late 1980s, there has been a concerted effort to maintain global commercial harvest of ocean fish at approximately 100 million metric tonnes (mmt). However, as global population grows, demand for fish and shellfish increases, and the percentage of aquatic products grown in aquaculture must likewise rise to meet the supply of those products. Projections for increased production are in the range of 40–100 mmt of new aquaculture production by about the year 2030 (Brown, 2003). Of the different agricultural food production systems, aquaculture is widely viewed as an important weapon in the global fight against malnutrition and poverty, particularly within developing countries where over 93% of global production is currently realized; the aquaculture sector providing in most instances an affordable and much needed food source rich in essential nutrients (Tacon et al., 2010). Aquaculture is the fastest-growing food production system globally, with a 9% increase in production of animal crops per year since 1985 (FAO, 2007). It fulfills a major role in feeding people today, and its potential for doing so in the future is large. Since natural fisheries rely on wild stocks, which are often overexploited, aquaculture can either exacerbate this overexploitation through damages to natural ecosystems (Naylor et al., 2000) or reduce it by alleviating pressure on wild fish stocks (Stotz, 2000).

A wide variety of animal and plant species are produced through aquaculture: finfish; shrimp, prawns and crabs; clams, oysters and mussels; as well as seaweeds and other aquatic plants. World aquatic plant production by aquaculture was 15.1 million tonnes in 2006. The culture of aquatic plants has increased consistently, with an average annual growth rate of 8% since 1970. In 2006, it contributed 93% of the world's total supply of aquatic plants. Some 72% originated in China, with 10.9 million tonnes. Virtually all of the remaining production also came from Asia: the Philippines (1.5 million tonnes), Indonesia (0.91 million tonnes), the Republic of Korea (0.77 million tonnes) and Japan (0.49 million tonnes) (FAO, 2005-2010). About 62% of all animals grown in aquaculture are finfish, 30% are mollusks, and 8% are crustaceans (FAO, 2005). Of the fishes currently grown worldwide, about 40% are carps and about 4% are salmon or tilapia (FAO, 2007). Aquaculture innovation produces a higher capital return to the farmer than traditional farming practices do, and such innovation can be a natural way of managing aquaculture production to become more sustainable (Diana, 2009).

World aquaculture is heavily dominated by the Asia-Pacific region, which accounts for 89% of production in terms of quantity and 77% in terms of value. This dominance is mainly due to China's enormous production, which accounts for 67% of global production in terms of quantity and 49% of global value. India stands a very distant second (almost by default) to the top producer China. China alone produces almost three fold more fish from aquaculture than the combined volume of the eleven next largest producers including India, Norway and Chile (Eknath and Jena, 2008).

Aquaculture

Aquaculture, also known as aquafarming, is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants in water under controlled conditions. In other words, it may be simply referred to as 'Underwater Agriculture'. Over the years, the enormous increase in the growth rate of aquaculture has been in response to declines in commercial harvests of wild stocks of fish and shellfish.

Each type of the above mentioned system of aquaculture has its own specific set of conditions and the total biomass production also varies from one system to the other. The selection of a particular aquaculture system is based mainly on the geographic location, type of water body, target aquatic species, availability of resources and skilled professionals, availability of seed of the target species at the desired time of stocking, apart from a set of different socio-economic factors.

Among all the aquatic organisms used for aquaculture, fishes have the dominant share with respect to number of species and production in quantity and value. Fish culture may be undertaken in almost any kind of water (be it freshwater/brackish water/ seawater or sewage water). A single species of fish may be selected for aquaculture or different combinations of compatible fish species may be utilized in order to produce more biomass. Fishes may be stocked in traditional community ponds, without supplementing artificial food and not taking care of the water body. Different types of aquaculture practices (http://enjoywithreal.com/2010/10/07/types-of-freshwater-aquaculture/) have been shown diagrammatically as follows:

Types of Aquaculture

On the basis of culture system

i) Traditional

ii) Improved traditional

iii) Continuous stocking and harvesting

On the basis of species composition

i) Mono culture

ii) Poly culture

On the basis of investment

i) Small scale aquaculture

ii) Large scale Aquaculture

On the basis of intensity

i) Extensive

ii) Semi-intensive

iii) Intensive

iv) Super- intensive

On the basis of construction

i) Cage culture

ii) Pen culture

iii) Raceway culture

On the basis of integration of different crops with fish

i) Exotic fish-cum-poultry culture

ii) Fish-cum- rice culture

iii) Vegetable fish

iv) Animal (cattle, pig, etc)-fish

In order to get better return, however, modern aquaculture practices have relied on intensification wherein very high stocking density of fishes are maintained on artificial feed and the water quality and environmental parameters are monitored to remain in the optimal range required for high growth rate of the fish. Fish culture may also be integrated with different crops or animals farming system. For example:

(i) Suitable species of fish may be cultivated in the rice fields having sufficient water required for fish survival and growth.

(ii) The bunds of ponds may be utilized for agricultural activities or animal farming.

In yet another type of aquaculture practice, specialized structures are constructed that are placed in natural water bodies. In such structures, the fishes are cultivated. Therefore, on the basis of requirement, resource availability and the number of other factors as discussed above, a particular aquaculture system may be adopted for the cultivation of the target species.

Indian perspective

Eknath and Jena (2008) have reviewed the status of Indian aquaculture. India is a major maritime state and an important aquaculture country in the world. Being home for more than 10% of global fish biodiversity, the country ranks third in the world in terms of total fish production. The contribution of inland fish production, however, has registered a remarkable trend- it has increased from about 25% to over 55%. With the present share of 95% of total aquaculture and over 40% of total fish production in the country, freshwater aquaculture is further poised to reach new heights in terms of enhancing production, productivity and profitability. Fish production from marine capture fisheries is likely to remain stagnant at its current level of production of about 3-3.3 million mt; contribution from fish enhancement practices will register a marginal increase from 0.7 to 1.6 million mt; mariculture and coastal aquaculture are likely to contribute only about 0.2 million mt and 0.4 million mt, respectively. Freshwater aquaculture has to be tapped to satisfy the demand for fish. It has to register a three-fold increase in production from the present 2.6 to about 6.7 million mt. The freshwater aquaculture systems in the country has primarily confined to three Indian major carps, viz., rohu, catla and mrigala, with exotic species: silver carp, grass carp, and common carp forming the second important group. Among the catfishes, magur (*Clarias batrachus*) has been the single species that has received certain level of attention both from the researchers and from farmers due to its high consumer preference, high market value and most importantly its suitability for farming in shallow and derelict water bodies with adverse ecological conditions. Recent years, however witnessed increasing interest for farming of *Pangasius* spp., especially in Koleru lake region of Andhra Pradesh due to its higher growth potential and ready market. Other potential species include *Labeo calbasu*, *Labeo gonius*, *Labeo bata*, *Labeo dussumeri*, *Labeo fimbriatus*, *Barbodes carnaticus*, *Puntius pulchellus*, *Puntius kolus*, *Puntius sarana*, and *Cirrhinus cirrhosa*. Some of these species are being cultured at a very low level in different parts of the country, mostly based on wild seed collection. The freshwater air-breathing and non air-breathing species, *Channa marulius*, *Channa striatus*, *Channa punctatus*, *Channa gachua*, *Channa stewartii* have not been taken up for the aquaculture activities in serious way. With the technology available for seed production and culture of air breathing (*Clarias batrachus*, *Heteropneustes fossilis*) and non air breathing catfish like (*Wallago attu*, *Mystus seenghala*, *Mystus aor*, *Horabagrus brachysoma*, *Pangasius pangasius*), scientific organized catfish farming can be taken up in extensive and semi intensive way (Ponniah and Sundaray, 2008). The giant freshwater prawn, *Macrobrachium rosenbergii* has been the principal species, adopted both under monoculture and under mixed farming of freshwater prawn production of about 43,000 tonnes in the country at present. However, *M. malcomsonii* and *M. gangeticum* have not been taken up in a big way.

The Indian scenario for the prospects of brackishwater and marine aquaculture has been presented by Ponniah and Sundaray (2008). In the brackishwater sector, the aquaculture development is mostly contributed by shrimp, *Penaeus monodon* culture only. The other shrimp species like *Fenneropenaeus indicus*, *Fenneropenaeus merguiensis*, *Penaeus pencillatus*, *Marsupenaeus japonicus* and *Penaeus semisulcatus* are not cultured on a commercial level large-scale culture. The finfish species like the seabass (*Lates calcarifer*) and grouper (*Epinephelus* spp.), grey mullet (*Mugil cephalus*), pearl-spot (*Etroplus suratensis*), milk fish (*Chanos chanos*) which are promising and ideal for aquaculture has not been exploited. The potential marine finfish species are *Epinephelus malabaricus*, *Epinephelus coioides, Epinephelus tauvina, Epinephelus fuscoguttatus, Epinephelus polyphekadion, Cromileptis altivelis*, *Rachycentron canadum*, *Seriola quinqueradiata*, *Trachinotus blochii*, *Coryphaena hippurus*, *Psettodes erumei, Lutjanus argentimaculatus*, and *Pampus argenteus*. Mariculture is expected to be a major activity in the Indian coastal areas in the years to come. Given the wide spectrum of cultivable species and technologies available, the long coastline and favorable climate, mariculture is likely to generate considerable interest among the coastal population and entrepreneurs. Seed production technologies for sea cucumber, seaweed, edible oyster, mussels and lobsters have been developed by Central Marine Fisheries Research Institute (CMFRI). Mussel culture has been taken up in some parts of Kerala.

India has achieved considerable production increases in aquaculture, especially in the production of freshwater fishes and shrimps. While progress in research and development of new technologies have already made, for example in mollusk culture and seaweed culture, these have not yet taken off as serious commercial ventures, and the production gaps between India and China or other important Asian countries are very wide. We could utilize much more effectively the diversity of our marine living resources for aquaculture, in the long coastline and expansive EEZ, and perhaps produce a few million tonnes of seaweeds, mollusks, and marine fishes annually through marine farming, if we go by the example of China and even other smaller Asian countries. Sustained aquaculture is currently the need in India as elsewhere. Eco-friendly aquaculture in harmony with environmental and socio-economic needs of the society has to be evolved. While we have considerable manpower in fisheries, much of it is technology aspects of aquaculture and recognize that the environmental and socio-economic impacts of aquaculture are grave concerns. New thrusts in research and manpower development should be there to ensure that eco-friendly and sustainable aquaculture is developed and that the benefits to the society are optimized through cooperative efforts (Kutty, 1999).

Advantages of aquaculture

Human demand for fish as food is growing steadily and aquaculture has established itself as an important source for the supply of excellent quality proteins and healthy oils. According to FAO, aquaculture production is already reaching almost 50% of the total fish production for human consumption, including marine and freshwater species. Some even say that the future of fish production lies with aquaculture (IUCN, 2007). Aquaculture has a significant positive contribution to food security through extensive and semi-intensive systems of production. There are fundamental social and economic differences between extensive/semi-intensive and intensive systems of production which have relevance for food security. Nutritional inputs in semi-intensive production can be on-farm by-products; even when off-farm fertilizers and supplementary feeds are purchased, they are cheaper than formulated feed used in intensive systems. Low cost inputs are affordable to poorer farmers and because the cost of production is low, the fish can be sold at a reasonable and affordable price to poor consumers. In contrast, fish cultured intensively can be marketed profitably only at a relatively high price because of the high production cost which puts them beyond the purchasing power of most consumers (Edwards, 1997).

Fish tend to retain the fatty acids that are in their diet. Thus, we can manipulate the fatty acid concentrations of fish and produce "designer fish" for targeted markets. Further, we can control the fat concentration in muscle through selected feed and produce a low-fat or high-fat fish depending on the demands of the market. Cultured aquatic animals can be safer products for consumption than wild fish because they are raised in a defined environment, and pollutants can be eliminated. Wild fish can be exposed to environmental pollutants and retain those they encounter. Organoleptic properties (taste) of fish and shellfish raised in aquaculture can be quite different from wild stocks. Fish flavour can be manipulated by dietary ingredients fed to the target species. If the diet contains a relatively high percentage of fishmeal, the fish can taste fishier than if the diet contains a relatively high percentage of corn and soybean products. Fish fed the latter diets are often described as "milder" tasting, which is a desirable characteristic in certain markets. There is also a taste consideration with environment. Some species can survive both fresh and saltwater but osmoregulation changes to meet the challenges of those environments. This physiological change affects taste because of the chemical compounds used to regulate ionic balance. A good example of this is the freshwater shrimp. When raised in freshwater, taste has been described as mild, whereas if the shrimp is placed in saltwater for one to two weeks, it will taste more like a marine shrimp (Brown, 2003). Therefore, aquaculture has the potential to supply good quality food to the growing human population as well as to increase the employment opportunities.

Disadvantages of aquaculture

Rapid growth in aquaculture practices raises many concerns too. The impact of aquaculture facilities and infrastructure may affect the local fauna and flora negatively, including threatened species. The effluents from aquaculture farms containing undesired chemicals and therapeutants might distress the local ecosystem. Farm escaped organisms can also have an impact. The use of exotic species in aquaculture is even more important, as they bring some risks such as the introduction of associated forms of life that come together with them (e.g. algae or microorganisms) or new pathogen agents that can spread out to a new environment. The source of food for cultivated fish, which normally consists of fish meal and fish oil, is another question to consider, as these primary products are made from small pelagic fishes whose origin might not be sustainable and even increase the already exaggerated pressure on existing fisheries (IUCN, 2007). Diana (2009) described the disadvantages of aquaculture practices as follows:

1. Escapement of aquatic crops and their potential hazard as invasive species.
2. Conversion of sensitive land areas such as mangroves and wetlands, as well as water use.
3. Other resource use, such as fishmeal and its concomitant overexploitation of fish stocks.
4. Disease or parasite transfer from captive to wild stocks.
5. Genetic alteration of existing stocks from escaped hatchery products.
6. Predator mortality caused by, for example, killing birds near aquaculture facilities.
7. Antibiotic and hormone use, which may influence aquatic species near aquaculture facilities.

Conclusion

It may be concluded that in the present era of food insecurity, aquaculture shows enormous potential to feed not only the ever increasing human population but also the aquaculture products can be utilized as a feed ingredient in the diets of different domesticated animals of high commercial value. The global developments and the strategic importance of aquaculture in terms of food security contribute to give aquaculture a promising future. The aquaculture sector has become a modern, dynamic industry that produces safe, high valuable and high quality products, and has developed the means to be environmentally sustainable. However, this industry is also facing a number of challenges. This strategy should deliver the best possible growth potential for the aquaculture industry, taking into account both our assets and constraints. Sustainable aquaculture is currently the need in India as elsewhere. Eco-friendly aquaculture in harmony with environmental and socioeconomic needs of the society has to be evolved. While we have considerable manpower in fisheries, much of it is technology oriented. We have to consider the multi-disciplinary aspects of aquaculture and recognize that the environmental and socio economic impacts of aquaculture are of great concerns. New thrusts in research and manpower development should be there to ensure that eco-friendly and sustainable aquaculture is developed and that the benefits to the society are optimized through cooperative efforts (Kutty, 1999). The rapid growth of the aquaculture sector has generated huge employment opportunities for professional, skilled and semi-skilled workers for the different support activities such as construction and the management of farms, hatcheries, feed mills, processing units etc. Aquaculture over recent years has not only led to substantial socio-economic benefits such as increased nutritional levels, income, employment and foreign exchange but has also brought vast un-utilized and under-utilized land and water resources under culture. With freshwater aquaculture being compatible with other farming systems, it is largely environmentally friendly and provides means for recycling and utilization of several types of organic wastes.

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