Integration of aquaculture into smallholder farming systems for improved food security and household nutrition

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Abstract

Aquaculture production techniques based on the culture of low-value herbivorous and/or omnivorous freshwater finfish in inland rural communities, within semi-intensive or extensive farming systems that use moderate to low levels of production inputs, have supplied large quantities of affordable fish for domestic markets and home consumption. Only recently have studies been initiated to assess the contribution of these integrated agriculture-aquaculture (IAA) systems to improved nutrition and food security, both within IAA farm households and in non-IAA households in the community. The effect can be direct, through within-household consumption and dietary improvement, but also indirect, through sale of fish produce and purchase of other food items (often at lower unit value than the sold fish). In the absence of in-depth studies, this contribution presents key elements from recent experiences in Africa and Asia that indicate where benefits from the integration of aquaculture into farming systems for human nutrition and food security can be achieved, and it recommends future avenues for research to provide much-needed information on the contribution of aquaculture to household nutrition and food security.

Introduction

The nutritional value of fish for the provision of essential nutrients that supplement those supplied by staples is well known [1]. In comparison to bulky staples, fish and other living aquatic resources (LARs) are considered nutrient-dense foods. Aside from protein and fatty acids, fish and other LARs provide highly bioavailable minerals and vitamins. This applies in general to most LARs, but some species have exceptionally high contents of particular micronutrients and are traditionally known for this in developing countries. For example, in Bangladesh, the small species locally known as *mola* (*Amblypharyngodon mola*) has a vitamin A content 20 times higher and a calcium content 10 times higher than commonly cultured fish species [1]. The high bioavailability of nutrients in LARs is an additional advantage for human nutrition. Moreover, the consumption of LARs or meats together with plant foods increases the bioavailability of minerals and vitamins from the latter sources.

The role of fish in human nutrition in developing countries varies from negligible to essential, depending on prevailing biophysical conditions and cultural traditions. Where LARs contribute to a major extent to the nutrition and food security of poor people in subsistence and semi-subsistence households, these originate mainly from the capture of wild fish [2, 3] or from the collection of "wild" fish from ditches and residual ponds towards the end of flood seasons [4, 5]. Aside from small wild fish species, a wide variety of organisms collected and utilized for human consumption, including insects, shrimps, crabs, snails, mussels, frogs, turtles, snakes, and also aquatic plants, are included in the term "living aquatic resources." In several countries, fishing and foraging on aquatic animals are the measure of last resort, even if only on a part-time or seasonal basis, to ensure survival when crops have failed or land resources are inaccessible.

In human diets, the share of animal proteins derived from fish varies from 30% in Asia to 20% in Africa and 10% in Latin America and the Caribbean. These shares have remained fairly stable over the last decades [6]. Within continents, per capita annual consumption varies considerably across countries. Despite an overall increase in the supply and consumption of fish globally, present consumption rates have been declining in many low-income, food-deficit countries and are expected to decline even further with greater overexploitation of inland and marine fisheries and with perceived demographic trends.

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In 24 countries (5 in Asia, 8 in Africa, and 11 in Latin America and the Caribbean) the annual per capita supply of fish food decreased by over 25% in the decade from the late 1980s to the late 1990s [2]. Over a longer time span, the trend in per capita food supply from 1961 to 1990 declined steadily in Bangladesh, Jamaica, Laos, Lebanon, Mauritania, Surinam, and Zambia [2]. In Bangladesh the per capita supply of fish food protein has been more than halved over this period, and it has not been replaced by other sources of animal protein, resulting in a net absolute decline in the intake of animal protein.

Aquaculture, the farming of fish and other LARs, is generally understood to have the potential to provide high-quality protein and micronutrients for human nutrition in developing countries [2]. Considerable increases in aquaculture production and value over the last decade have resulted mainly from gains from a few high-value species such as shrimp and salmon grown in high-input systems, and from the intensified use of large ponds and reservoirs in China and India through stocking and feeding of carp polycultures supplying the domestic market.

In three decades of aquaculture research and extension efforts targeting smallholder producers in developing countries, the main objective has been to induce poor farmers to adopt fish farming as a single enterprise based on a single technology package. These efforts have had limited success in Asia and Latin America and have essentially failed in Africa.

In the past decade, a new farmer-focused systems approach has been adopted in which an aquaculture activity is incorporated into existing farming systems based on the household's resources, capacity, and needs [7, 8]. This diversification, in the form of integrated agriculture–aquaculture (IAA), is only successful when requirements for investments (e.g., pond construction, feeds, and fertilizer) are minimal and the use of existing on-farm and near-farm resources can be optimized, for example, through recycling of residues. The resulting location-specific solutions are highly varied and cannot be simply extended in the form of a standard technology package. A flexible participatory strategy has provided sustainable results when introducing IAA to new-entrant farm households [9, 10].

These small-scale IAA farming systems are perceived to have great potential for providing nutritional as well as economic benefits to the rural poor [11]. Usually targeted at subsistence and semi-subsistence households, the underlying assumption is that most of their production is consumed by the producing household themselves and only a small portion is shared or traded with neighbours, which has been shown for remote locations [12]. In areas of poor transport infrastructure, such as Malawi, most fish is marketed and consumed within the rural communities in the vicinity of the farms [13], a practice that is enforced by social pressure against marketing of fish outside the community.

Only very recently have studies been initiated to assess the actual contribution of aquaculture to household nutrition and food security, the most thorough of which are two studies conducted in Bangladesh [14, 15]. Therefore, this contribution presents elements and available data from recent experiences in Africa and Asia that indicate where benefits from the integration of aquaculture into farming systems for human nutrition and food security can be achieved. Additionally, given the dearth of adequate information, recommendations are made as to future research needs.

Integrated agriculture–aquaculture systems and nutritional benefits

Aquaculture has been successfully adopted by small farmers in situations in which the local demand for fish and other LARs is high because of a decline in supply from naturally fished stocks, a reduction in the per capita supply as a result of human population growth, rising incomes of the middle class, and urbanization. Additionally, where occupational traditions exist for part-time fisheries in various types of freshwaters, the propensity to embark on aquaculture, i.e., husbandry of LARs, is often higher.

In such cases, aquaculture can contribute to meeting the demand through culture of species accepted by consumers, either introduced or indigenous species. Technologies requiring low levels of investment, labour, and material inputs have been developed and adopted by farmers. Management of existing seasonal or perennial water bodies by individual households, but more often by communities, can be the easiest entry level into aquaculture. More contained operations are rice-and-fish systems, in which farmers already have the skill of water management. The management of ponds requires higher levels of experience. With increased levels of management and inputs for greater outputs, the systems also become more vulnerable to mistakes and perturbations (e.g., overfertilization or disease outbreaks at high stocking densities). Experience has shown that low entry-level technologies with modest production provide a low-risk start to a learning curve over several years that new entrants must go through.

With experience, further increases in productivity can be achieved through greater levels of inputs, such as feeds and fertilizers. Additionally, genetic improvements in growth performance and survival of fish can achieve gains within low-input systems, although profits will be higher in higher-input systems [16, 17].

In all of the above situations, it is generally assumed that increased production and accessibility of fish to the poor will also lead to greater consumption, with resultant benefits to nutrition and livelihoods. Direct measurements of the nutritional impact of aquaculture are almost never conducted.

In the following, recent examples of IAA introductions are outlined for Africa and Asia together with elements indicating nutritional and food-security benefits. In the highlighted cases, factors and issues considered to impinge on the nutritional impact of IAA in their respective sociocultural, political, economic, and agroecological environments are presented.

Africa

The modification of natural resource types to better cope with drought situations can lead to improved food security. In Malawi the introduction of ponds has been shown to make farms more resilient under drought conditions through diversification into aquaculture and vegetables, and the capability to produce a crop of marketable vegetables in dried-out ponds, which still contain residual moisture in their bottom soils [18]. Thereby these farm households with IAA systems were able to subsist from their own production and income over the entire drought, while non-IAA farms were dependent on food aid.

In many countries a "hungry season" is common in the annual farming calendar between the depletion of food stores and the main crop harvest. For such defined and recurrent seasons, which are periods of severe household stress, an aquaculture operation can be designed and scheduled to provide fish and vegetables to counter the usual undersupply of essential nutrients. Appleton [19] used a food-consumption calendar with semi-quantitative data as a participatory tool for rapid assessment of community nutrition in Zambia. The results were later used by a development project to design appropriate actions, but further quantifications of fish consumption resulting from interventions were not conducted.

In the southern region of Malawi, a country with severe poverty and malnutrition, there is a high demand for fish within local rural communities, so that fish produced in ponds on smallholder farms is sold exclusively on the farms (essentially to neighbours) by 44% of the farmers, sold on the farms and also in nearby markets (at a maximum distance of 5 km) by 42%, and sold exclusively in markets by only 14% [13]. Farmers face considerable social pressure to market fish within the same community [Brummett RE, personal communication, 1999].

In the central region of Malawi, a household nutritional study on fish-farming and non-fish-farming households over a four-week period found that there was no difference in nutritional status between them: the stunting rates of children (height-for-age < 2 SD of National Center for Health Statistics standards) was 25% in households with fish ponds and 29% in households without fish ponds [20]. Undernutrition of children occurred in 33% of households in both groups.* It was not reported what type of aquaculture system design was used, but fish consumption was very low; only 5% of surveyed households consumed pond-raised fish at least once per month. Fish cultured with the main intention to be marketed, particularly species of larger size, are usually harvested once at the end of the culture cycle. Inadequate knowledge of intermediate harvest methods, using alternative species intended for home consumption, and inappropriate system design are perceived as the reason for minimal own-consumption. These flaws were later addressed in research activities in subsequent projects in other areas, e.g., introduction of small species in polycultures and research into, and training in, intermittent harvest techniques [21].

In Ghana, a study estimated the potential household nutritional impact of the adoption of an IAA component by smallholder farmers in three different agroecological zones with a total of eight different farming systems [22]. It was concluded that considerable economic and nutritional benefits could be gained by the farmers in the inland regions away from the coast, which has an ample supply of marine fish, but with favourable water availability and soil quality to enable pond construction and operation. Required intakes could be met through the inclusion of the fish-vegetable enterprise.

Asia

In Bangladesh, a study found that there are fewer communal water bodies today than there were 16 years ago as a result of conversion of these areas into flood-controlled and irrigated rice-growing fields [4]. These areas are an important source of supply of small indigenous fish, of which there are several dozen species and which are an important part of the diet of the people in Bangladesh. About one dozen species are recognized by rural women to have specific nutritional and also medicinal characteristics. They are caught in floodplains by part-time fishing during the flooded season [1]. Today their availability from floodplains is considerably reduced, as evidenced by their increased unit price in the rural markets. The halved per capita total supply of fish in Bangladesh (a major portion of which consists of small indigenous species caught in the floodplains) is expected to have had subsequent negative effects on household nutrition through reduced dietary diversification and availability of

* Anthropometry is a blunt instrument for measuring nutritional impacts of increased fish consumption. In any event, there may have been systematic differences between adopting and non-adopting households apart from aquaculture production that might explain observed differences in anthropometry.

micronutrients. Aquaculture experiments on these small species are under way, but their economics are not promising to date.

The culture of fish in rice fields is based on the natural occurrence of various LARs in rice fields, and these have historically played an important role in supplying protein and micronutrients to rice-farming households and particularly to landless labour households. In the Philippines, the LARs in rice fields are regarded as common property. By tradition anyone can catch them [23]. Nevertheless, households of rice-and-fish farmers have been found to consume more fresh fish than households without a rice-and-fish operation. Problems often arise from the tradition of common access to LARs in rice fields if fields are intentionally stocked with fish fry at a considerable cost to the farmer; it is socially very difficult to restrict access to the poor in the community on the grounds of this investment alone [23]. In Bangladesh, the benefits of rice-and-fish culture as identified by farmers are primarily as a source of additional income and as additional food for the family [24].

The fish output from existing excavation pits used as small ponds or from newly constructed fish ponds of small farmers in Bangladesh is perceived to be mainly for household consumption and secondarily for cash income [25]. In Quirino Province in the Philippines, a study introducing integrated aquaculture to farm households within the context of forest buffer zone management found that fish grown in ponds were used essentially for home consumption, with few fish given away, owing to the remoteness of the farms from markets and the lack of transport infrastructure [12]. Aside from pond fish, a variety of aquatic organisms, such as snails, bivalves, shrimps, crabs, frogs, and small fish, are caught from rice fields and streams and consumed regularly in the household or as part of meals prepared on site during fieldwork.

The benefits to women-headed households of such aquaculture operations have been found to be considerable, owing to appropriate technology designed in partnership with the women, and have led to substantial improvement of the livelihoods of the women and dependents [26]. On the other hand, the nutritional and economic benefits of the operation of ponds by women's groups may be less measurable [14]. Additionally, in cases where the ponds are not under the group's ownership, a lease may be revoked once the owner recognizes the possible gains, following the example of the successful women's group, as has been frequently the case in Bangladesh.

A study in Kapasia in Bangladesh, in which the impact of an earlier extension effort was assessed five years later, revealed that different improved technologies disseminated to farmers led to different disposal patterns (household consumption of pond grown fish after technology introduction as percentage of total production: carp polyculture 20%, tilapia monoculture 67%, silver barb monoculture 33%) compared with the situation before the new technology was introduced (before intervention, 33% was consumed at home, and the rest was mainly sold).* A one-year household food-consumption study of the impact of the earlier intervention in the same area revealed that households with small farms consumed fish on 80% of the days of the year, whereas those with medium and large farms consumed fish on 86% and 88% of the days of the year, respectively [15]. Households with small farms (0.2–1.0 hectare) consumed 15 kg fish/month or 83 g/person/day, compared with 11 kg (no per capita data given) by landless households (0–0.2 hectare), 15 kg/month or 85 g/person/day by households with medium-sized farms (1.0–3.0 hectares), and 18 kg/month or 96 g/person/day by households with large farms (over 3.0 hectares).** Owners of medium and large ponds tend to sell the majority of their cultured fish, in contrast to owners of small ponds, who consume most of their fish in the household.

Future research

In the past decades, the most significant aspect of the development of aquaculture around the world has been the steady increase in the production of fish species grown on agricultural farms in low-income, food-deficit countries. The polyculture technology has shown the potential to increase the growth rate of supply. Aquaculture production techniques based on culture of low-value herbivorous or omnivorous freshwater finfish in inland rural communities, within semi-intensive or extensive farming systems that use moderate to low levels of production inputs, have supplied large quantities of affordable fish for domestic markets and home consumption [27].

Fish prices and household incomes are important determinants of fish consumption. As a food group, fish tend to have high income elasticities, i.e., fish consumption rises rapidly with income. When fish prices rise, as has happened in Bangladesh, the poor probably cut back on fish consumption in percentage terms more than the rich. Such cutbacks by the poor,

* Ahmed M, Lorica MH. Improving developing country food security through aquaculture development: socioeconomic and policy issues. Paper presented at World Aquaculture '99, the Annual International Conference and Exposition of the World Aquaculture Society, 26 April–2 May 1999, Sydney, Australia, 1999.

** Sultana P. Household fish consumption and socioeconomic impacts in Kapasia. Paper presented at the Workshop on Aquaculture Extension: Impacts and Sustainability, 11 May 2000, Dhaka. Penang, Malaysia: International Center for Living Aquatic Resources Management, and Dacca, Bangladesh: Department of Fisheries, 2000.

who are already nutritionally stressed, may be serious, although no empirical estimates of lowered nutritional status are available. Raising the incomes of the poor is very much a long-term strategy for increasing fish consumption and overall dietary quality. Lowering fish prices is a possible medium-term strategy if the rate of growth of supply can be increased faster than demand. By concentrating on low-value and/or small and indigenous fish species, which are usually less in demand by high-income consumers, it may be possible to keep the prices of these species down for poorer consumers.

There are several research questions that need be answered before one can see a clear link between the supply of certain types of fish and improvements in the nutritional status of the poor people in the developing countries. Future nutrition analyses should probably concentrate less on nutritional impacts of aquaculture adopters (inevitably a small proportion of the total population) and more on poor consumers (a group that includes poor producers). The most difficult research issue perhaps will be to obtain estimates of the effects of consumption of particular fish species on nutrition (e.g., micronutrient status as measured by blood analysis). At minimum this will require laboratory analysis of various fish species for their nutritional content. It will be important to understand factors driving demand patterns (e.g., price and income elasticities) for specific types of fish. The production potential of various species, of course, is a key issue on the supply side. Fish are part of an overall diet. Research on dietary diversification, trends in food habits, and changes in lifestyles, living conditions, and consumption patterns among the poor and working class in rapidly urbanizing societies will also be useful for recommending investments in fish species and farming systems development for aquaculture that take into account impacts on nutritional status.

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