The potential of nutrient-rich small fish species in aquaculture to improve human nutrition and health

Invited Guest Lecture 2

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Abstract

Small fish are a common food and an integral part of the everyday carbohydrate-rich diets of many population groups in poor countries. These populations also suffer from undernutrition, including micronutrient deficiencies – the hidden hunger. Small fish species, as well as the little oil, vegetables and spices with which they are cooked enhance diet diversity. Small fish are a rich source of animal protein, essential fatty acids, vitamins and minerals. Studies in rural Bangladesh and Cambodia showed that small fish made up 50–80 percent of total fish intake in the peak fish production season. Although consumed in small quantities, the frequency of small fish intake was high. As many small fish species are eaten whole; with head, viscera and bones, they are particularly rich in bioavailable calcium, and some are also rich in vitamin A, iron and zinc. A traditional daily meal of rice and sour soup, made with the iron-rich fish, "trey changwa plieng" (Mekong flying barb, *Esomus longimanus*), with the head intact can meet 45 percent of the daily iron requirement of a Cambodian woman. Small fish are a preferred food, supplying multiple essential nutrients and with positive perceptions for nutrition, health and well-being. Thus, in

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areas with fisheries resources and habitual fish intake, there is good scope to include micronutrient-rich small fish in agricultural policy and programmes, thereby increasing intakes which can lead to improved nutrition and health. The results of many studies and field trials conducted in Bangladesh with carps and small fish species have shown that the presence of native fish in pond polyculture and the stocking of the vitamin A-rich small fish, "mola" (mola carplet, *Amblypharyngodon mola*), did not decrease the total production of carps; however, the nutritional quality of the total fish production improved greatly. In addition, mola breeds in the pond, and partial, frequent harvesting of small quantities is practiced, favouring home consumption. A production of only 10 kg/pond/year of mola in the estimated four million small, seasonal ponds in Bangladesh can meet the annual recommended intake of six million children. Successful aquaculture trials with polyculture of small and large fish species have also been conducted in rice fields and wetlands. Thus, aquaculture has a large, untapped potential to combat hidden hunger. To make full use of this potential, further data on nutrient bioavailability, intra-household seasonal consumption, nutrient analyses, cleaning, processing and cooking methods of small fish species are needed. Advocacy, awareness and nutrition education on the role small fish can play in increasing diet diversity and micronutrient intakes must be strengthened. Measures to develop and implement sustainable, low-cost technologies for the management, conservation, production, preservation, availability and accessibility of small fish must be undertaken. Also, an analysis of the cost-effectiveness of micronutrient-rich small fish species in combating micronutrient deficiencies using the Disability-Adjusted Life Years (DALYs) framework should be carried out.

KEY WORDS: *Aquaculture, Fish species consumption, Human nutrition, Micronutrients in fish species, Nutrient-rich small fish species.*

Introduction

Drawing mainly on data from Bangladesh and Cambodia, this paper focuses on the importance of nutrient-rich small fish in aquaculture in supplying essential nutrients, in particular vitamin A, calcium, iron and zinc to vulnerable population groups. In developing countries with fish resources, fish and fisheries play an important role in the livelihoods, income and diets of many, especially the rural poor, who also suffer from undernutrition, including micronutrient – vitamin and mineral – deficiencies, termed "hidden hunger". It is estimated that 190 million children worldwide are affected by vitamin A deficiency; two billion people have an insufficient iodine intake; 1.6 billion (almost 25 percent) of the world's population are anaemic, half of this due to iron deficiency; and many suffer from zinc deficiency.[1]

[1] World Health Organization. Vitamin and mineral nutrition information system (VMIS). Micronutrient database (accessed May 2011; available at: www.who.int/vmnis/database/en).

These deficiencies increase the risk of morbidity and mortality from diarrhoea and measles, cause xerophthalmia and anaemia, and negatively affect growth and cognitive development in children, reproductive performance and work productivity. It is estimated that maternal and child undernutrition accounts for 11 percent of total Global Disability-Adjusted Life Years (DALYs), with dire consequences for national and global development (Black *et al.,* 2008). Aquaculture technologies which include nutrient-rich small fish in polyculture of carps and freshwater prawn have shown great potential in alleviating hidden hunger.

Fish species consumption in bangladesh and cambodia

Official estimates of fish production and consumption tend to exclude the fish caught, consumed and traded in rural areas, and therefore the benefits that are derived from fish are not well documented and are grossly underestimated. In addition, the data from surveys in which food consumption has been reported do not include intra-household consumption or fish consumption at the species level. Consumption surveys in selected areas of rural Bangladesh showed that the amount of fish consumed varies with location and household economic status, and is highly seasonal. Fish was the third most commonly consumed food, after rice and vegetables. In poor households with little land, the mean fish intake ranged from 13 to 83 g of raw, whole fish/person/d (Thompson *et al*., 2002).

In a study conducted in 84 households in Kishoreganj, Bangladesh in three rounds (July 1997, October 1997 and February 1998), the highest total fish intake was recorded in October, with small indigenous fish species (SIS, growing to a maximum length of 25 cm or less) making up a much greater proportion (84 percent) of the total fish intake than large fish. Five species: “puti” (barbs, *Puntius* spp.), silver carp (*Hypophthalmichthys molitrix*), “taki” (spotted snakehead, *Channa punctata*), “baim”/”chikra” (lesser spiny eel, *Macrognathus aculeatus*; zig-zag eel, *Mastacembelus armatus*; barred spiny eel, *Macrognathus pancalus*), and “mola” (mola perchlet, *Amblypharyngodon mola*), in descending order of percentage of total fish intake, made up 57 percent of the total fish intake. The SIS, “puti”, covering 10 species, with three (*P. sophore, P. chola and P. ticto*) being the most commonly consumed, both fresh and fermented, made up 26 percent of total fish intake, calculated as raw, edible parts. The frequency of fish, especially SIS, consumption was high; nearly all households consumed SIS on at least one out of five consecutive days (Roos, Islam and Thilsted, 2003a). Thus, SIS is an integral part of the everyday, rice-dominated diet, and with the little oil, spices and vegetables with which they are cooked enhance diet diversity.

In a small study conducted in 66 poor, rural households in Svag Rieng Province, Cambodia in 1997–1998, an average intake of 70 g raw, edible parts of fish/

person/d, as well as 9 g/person/d of other aquatic animals (OAA, for example, frog, snail and snake) were recorded (Toft, 2001). In fish communities around Tonle Sap Lake, Cambodia, it was estimated that the average fish intake was 128 g raw, cleaned parts/person/d in 1998 (Ahmed *et al.*, 1998).

These studies showed that small fish made up 50–80 percent of all fish eaten in the peak fish production season in rural Bangladesh and Cambodia. There are increasing concerns that fish intakes in these countries, as well as in other developing countries are decreasing due to factors such as population growth, increased urbanization, rising incomes and high consumer preferences for fish, especially in Asia. In Cambodia, there are concerns that the construction of dams on the Mekong River will decrease the amount of fish caught. In Bangladesh, changes in the overall agricultural system, especially rice production, as well as in the use of land and water cause continued decline in the areas of inland water and inundation, reducing the habitats for fish and cutting off migratory routes from breeding grounds. This has contributed to decreased fish intake, in particular SIS intake among the rural poor. Concomitantly, the intake of silver carp from pond aquaculture has risen and the proportion of SIS in the total fish intake has decreased (Thompson *et al.,* 2002).

In the above-mentioned study in Kishoreganj, Bangladesh, the rural market was the most important source of fish, 57–69 percent of the total fish intake being derived from this source, while fish caught by household members accounted for 16–37 percent of total fish intake. Market prices of fish varied considerably; in the lean fish production season (July), the prices were nearly double those in the peak season (October). "Puti" and mixed SIS were cheapest, and most SIS were cheaper than large fish, with the exception of silver carp, which was as cheap as many SIS (Roos *et al.,* 2007d).

In recent years, "mola" has become common in markets and supermarkets in the capital, Dhaka. The demand for "mola" may have increased due to the awareness of it being beneficial for nutrition and health, in spite of its high price, much higher than many carp species. Also, the amounts of Nile tilapia (*Oreochromis niloticus*) and "pangas" (striped catfish,*Pangasianodon hypophthalmus*) available in urban markets are increasing due to large-scale aquaculture production.

Nutrient contents of some common fish species

Table 1 shows the vitamin A, calcium, iron and zinc contents of some common fish species in Bangladesh and Cambodia (Thilsted, Roos and Hassan, 1997; Roos *et al.,* 2007c). Some common SIS have high contents of preformed vitamin A, mainly as retinol (vitamin A-1) and 3,4-dehydroretinol isomers (vitamin A-2). The proportions of vitamin A-1 and A-2 vary considerably between species. In "chanda" (Himalayan glassy perchlet, *Parambassis baculis*), vitamin A-2

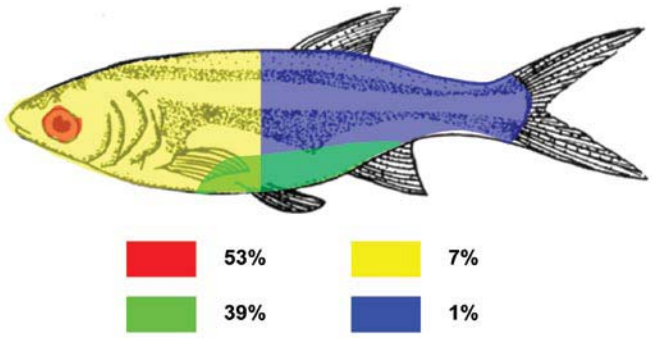
TABLE 1
Vitamin A, calcium, iron, and zinc contents in selected common fish species in Bangladesh and Cambodia[1]

Common name[2]	Scientific name	Contents per 100 g raw, cleaned parts					
		Vitamin A (RAE)[3]		Calcium (g)	Calcium[4] (g)	Iron (mg)	Zinc (mg)
		mean ± SD (n)[5]					
Bangladesh							
SIS[6]							
Baim/Chikra (Lesser spiny eel)	*Macrognathus aculeatus*	90	± 15 (3)	0.4 ± 0.1 (5)	0.2 ± 0.0 (5)	2.4 ± 0.4 (5)	1.2 ± 0.2 (5)
(Barred spiny eel)	*M. pancalus*	90	(1)	—[7]	—	—	—
(Zig-zag eel)	*Mastacembelus armatus*	30	(1)	—	—	—	—
Chanda (Indian glassy fish)	*Parambassis ranga*	1 679	± 1 000 (3)	1.0 ± 0.3 (5)	0.9 ± 0.3 (5)	1.8 ± 0.7 (5)	2.3 ± 0.6 (5)
(Himalayan glassy perchlet)	*Pseudambassis baculis*	340	± 105 (3)	—	—	—	—
(Elongate glass-perchlet)	*Chanda nama*	170	(1)	—	—	—	—
Darkina (Flying barb)	*Esomus danricus*	890	± 380 (3)	0.9 ± 0.4 (3)	0.8 ± 0.3 (3)	12.0 ± 9.1 (3)	4.0 ± 1.0 (3)
Dhela	*Ostreobrama cotio cotio*	937	(1)	1.3	—	—	—
Kachki (Ganges river sprat)	*Corica soborna*	90	± 20 (7)	0.5 ± 0.0 (2)	0.4 ± 0.0 (2)	2.8 ± 1.2 (2)	3.1 ± 0.5 (2)
Mola (Mola carplet)	*Amblypharyngodon mola*	2 680	± 390 (7)	0.9 ± 0.1 (3)	0.8 ± 0.0 (3)	5.7 ± 3.7 (3)	3.2 ± 0.5 (3)
Puti (Pool barb)	*Puntius sophore*	60	± 20 (3)	1.2 ± 0.2 (4)	0.8 ± 0.1 (4)	3.0 ± 0.9 (4)	3.1 ± 0.5 (4)
(Swamp barb)	*P. chola*	70	(1)	—	—	—	—
(Ticto barb)	*P. ticto*	20	(1)	—	—	—	—
Taki (Spotted snakehead)	*Channa punctata*	140	± 45 (3)	0.8 ± 0.2 (3)	0.3 ± 0.1 (3)	1.8 ± 0.4 (3)	1.5 ± 0.2 (3)
Commonly cultured large fish species: carps							
Mrigal (Mrigal carp)	*Cirrhinus cirrhosus*	< 30	(1)	1.0 ± 0.1 (3)	0.0 ± 0.0 (3)	2.5 ± 1.3 (3)	—
Silver carp	*Hypophthalmichthys molitrix*	< 30	(3)	0.9 ± 0.4 (3)	0.0 ± 0.0 (3)	4.4 ± 1.8 (3)	—
Cambodia							
SIS							
Changwe mool (Yellowtail rasbora)	*Rasbora tornieri*	374	± 111 (3)	0.7 ± 0.0 (3)	—	0.7 ± 0.1 (3)	2.7 ± 0.2 (3)
Chunteas phluk	*Parachela siamensis*	480	± 35 (3)	0.6 ± 0.1 (3)	—	1.2 ± 0.3 (3)	2.2 ± 0.1 (3)
Kangtrang preng (Duskyfin glassy perchlet)	*Parambassis wolffi*	260	(1)[8]	1.1 ± 0.1 (3)	—	1.4 ± 0.5 (3)	1.6 ± 0.3 (3)
Trey changwa plieng (Mekong flying barb)	*Esomus longimanus*	415	(1)	0.8 ± 0.2 (3)	—	11.3 ± 3.4 (5)	4.9 ± 0.5 (3)
Commonly cultured large fish species: snakeheads							
Indonesian snakehead	*Channa micropeltes*		—	1.1 ± 0.1 (3)	—	1.2 ± 0.1 (3)	1.4 ± 0.1 (3)
Great snakehead	*C. marulius*	200	(1)[8]	1.4 ± 0.2 (3)	—	1.5 ± 0.9 (3)	1.5 ± 0.1 (3)

[1] *Source:* Thilsted, Roos and Hassan (1997), Roos *et al.* (2007c).

[2] Fish species are listed in alphabetical order of local common name in each subgroup. Where available, FishBase recognized common names (www.fishbase.org/) are given in parentheses.
[3] RAE = retinol activity equivalent.
[4] In raw, edible parts, after correcting for calcium in the plate waste (mainly bones).
[5] n = number of samples. For SIS, a sample consisted of 10–300 fish and for large fish, 1–2 fish.
[6] SIS = small indigenous fish species.
[7] — = not measured.
[8] Measured in raw, whole fish.

FIGURE 1
Distribution of vitamin A in "mola". Vitamin A content: 2,680 RAE[1]/100 g raw, edible parts. Length of whole "mola": 6–8 cm; weight of raw, whole "mola": 5–9 g.[2]



[1] RAE: retinol activity equivalent.
[2] *Source:* Roos *et al.* (2002).

accounts for 90 percent of the total vitamin A content, expressed as retinol activity equivalent (RAE), and 20 percent in "darkina" (flying barb, *Esomus danricus*). Analysis of the different parts of mola showed that the eyes contain the highest proportion of the total vitamin A, followed by the viscera (Figure 1) (Roos *et al.,* 2002, 2007a; Roos, Islam and Thilsted 2003a, b). As most SIS are eaten whole with bones, they are a very rich source of calcium. The two *Esomus* species, "darkina" from Bangladesh and "trey changwa plieng" (Mekong flying barb, *E. longimanus*) from Cambodia have significantly higher iron content than the other analyzed species. Iron in fish is in the form of haem iron, a high molecular subpool of complex-bound non-haem iron, and inorganic iron, the proportions varying with species. These two fish species also have a high zinc content (Roos *et al*., 2007b).

The nutritional contribution of fish species

Fish, and in particular small fish species are a rich animal-source food of multiple essential nutrients. It is well recognized that all fish species are a rich source of animal protein, and some have a high fat content and beneficial polyunsaturated fatty acids. However, there has been little focus on the contribution of fish as a rich source of vitamins and minerals. In the above-mentioned study in Kishoreganj, Bangladesh, SIS contributed 40 percent and 31 percent of the total recommended intakes of vitamin A and calcium, respectively, at the household level, in the peak fish production season (Roos *et al.,* 2006).

In order to quantify the nutritional contribution of a fish species, it is important that the cleaning practices be documented, the discarded parts recorded and weighed before cooking or processing, and with respect to raw fish, nutrient analyses be carried out on samples of raw, cleaned parts, and the plate waste recorded and analyzed. Processing of fish is a common practice; in Bangladesh, some SIS and small prawn are dried, and some SIS are also fermented in the peak production season. In Cambodia, a proportion of fish is consumed as fish paste, fish sauce, dried salted fish, fermented and smoked fish (Chamnan *et al.,* 2009).

Sun-drying of "mola" resulted in nearly all vitamin A being destroyed (Roos, Islam and Thilsted, 2003b). As the majority of vitamin A in "mola" is found in the eyes, to ensure a high vitamin A contribution, it is important that the head is not removed during cleaning, but cooked, and the head and eyes are consumed, which is a common practice.

In Kandal Province, Cambodia, it was recorded that the majority (80 percent) of households cooked "trey changwa plieng" with the head intact. Calcium, iron and zinc contents in raw, cleaned samples with head were considerable higher (58, 25 and 53 percent, respectively) than in samples in which the head was discarded during cleaning (Thorseng and Gondolf, 2005). With respect to calcium contribution, the size of the fish and the plate waste are important factors. Large fish (e.g. carps) do not contribute to calcium, as the bones are plate waste (Table 1). SIS are generally eaten whole, without plate waste, making them an extremely rich source of calcium.

The bioefficacy of preformed vitamin A and bioavailability of minerals in fish species are major factors for determining their nutritional contribution. A biological activity of 40 percent in relation to all-*trans* retinol is used to calculate RAE from vitamin A-2 in fish samples, based on the growth response of vitamin A-2 in rats (Shantz and Brinkman, 1950). Calcium in "mola" was shown to have the same high bioavailability as that from milk in both rats and humans (Hansen *et al*., 1998; Larsen *et al.,* 2000). The bioavailability of the iron fractions found in fish is estimated to be 25 percent for both haem iron and the complex-bound non-haem iron, and 10 percent for inorganic iron. The cooking method can affect bioavailability: a Cambodian fish dish of boiled "trey changwa plieng" contained more haem iron than one that was fried (Roos *et al.,* 2007b). Zinc bioavailability from animal-source foods, including fish is considered to be high.

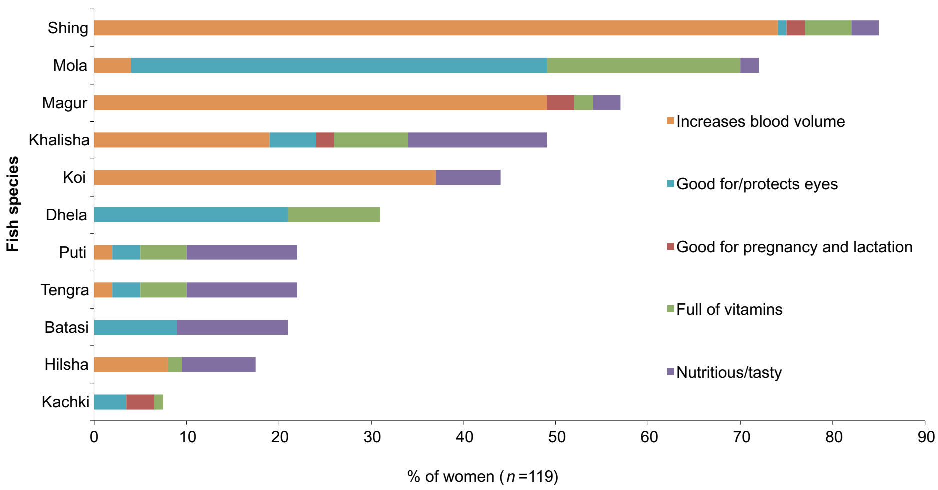
Boiled rice and sour soup is one of the most common, traditional meals consumed by poor, rural households in Cambodia. An average meal consumed by women consisted of 367 g boiled rice/woman/meal and 257 g sour soup containing 49 g fish/woman/meal. If the sour soup is prepared with "trey changwa plieng", this traditional meal can meet 45 percent of the daily median iron requirements of a Cambodian woman. An intake of 100 g sour soup containing 25 g "trey changwa plieng" in a child's meal would contribute 42 percent of the daily median iron requirement (0.45 mg iron/child/d) (Roos *et al.,* 2007b). Moreover, besides providing easily absorbable iron, fish has been shown to have an enhancing effect on non-haem iron and zinc absorption from the meal in humans (Aung-Than-Batu, Thein-Than and Thane-Toe*,* 1976).

Perceptions of fish species for nutrition, health and well-being

Figure 2 shows the 11 fish species which received the highest ratings in a study among rural Bangladeshi women, in 1991/92 with respect to their perceptions of the benefits of eating fish species for nutrition, health and well-being. "Mola" and "dhela" (*Ostreobrama cotio cotio*), with high vitamin A content were reported as being full of vitamins and good for the eyes (Thilsted and Roos, 1999). In a study in two fishing villages in Bangladesh, one floodplain and the other coastal, the same fish species were noted to have similar positive perceptions among local communities (Deb and Haque, 2011).

In the above-mentioned household survey in Kishoreganj in 1997/98, all household members (*n*=481, mothers reporting for children) were asked to name the fish species most preferred for consumption. "Rui" (roho labeo, *Labeo rohita*), a large indigenous carp was the most preferred species (reported by 24 percent of the respondents), followed by "mola" (13 percent) and "hilsha" (hilsha shad, *Tenualosa ilisha*) (11 percent). A SIS (with the exception of "puti") was the most preferred species by 30 percent of the respondents, whereas "puti" and silver carp, the species with the highest intakes were preferred by less than 10 percent of the respondents (Roos, 2001). In a later study of 36 women and men

FIGURE 2
Perceptions of fish species by Bangladeshi rural women[1, 2]



[1] The 11 species with the highest rankings are shown.
[2] Fish species are listed in alphabetical order by local common name. Where available, FishBase recognized common names and scientific names (www.fishbase.org) are given in parentheses: Batasi (Indian potasi, *Pseudeutropius atherinoides*), Dhela (*Ostreobrama cotio cotio*), Hilsha (hilsha shad, Tenualosa ilisha), Kachki (Ganges river spart, *Corica soborna*), Khalisha (banded gourami, *Colisa fasciata*), Koi (climbing perch, *Anabas testudineus*), Magur (walking catfish, *Clarias batrachus*), Mola (mola perchlet, *Amblypharyngodon mola*), Puti (barbs, *Puntius* spp.), Shing (stinging catfish, *Heteropneustes fossilis*), Tengra (bagrid catfish, *Mystus* spp.).

Source: Thilsted and Roos (1999).

in three Bangladeshi villages, it was reported that although women were aware of the value of "mola" and "dhela" as a rich source of vitamin A, and being good for the eyes, especially for pregnant and lactating women; it was difficult to promote increased intakes in these vulnerable groups. The major constraints were low availability and accessibility of these SIS, as well as little importance given to the nutritional needs of women by men and mothers-in-law, key decision-makers in the family (Jeppesen, 2006).

Small fish species are a preferred animal-source food

SIS enjoy the status of being a preferred, everyday food, well-liked by all household members and with a high frequency of consumption. This, coupled with the positive perceptions of some small fish species as being good for nutrition and health, as well as reports that a dish made with small fish is more equitably shared among all household members (in contrast to one made with large fish) can be capitalized on to promote the consumption of micronutrient-rich fish species, especially in vulnerable population groups such as young children, pregnant and lactating women, the sick and elderly. Thus, micronutrient-rich small fish species hold an extremely favourable position for being included in the design and implementation of agricultural policy decisions and programmes to increase the intakes of animal-source foods in women and children.

Data from Bangladesh validate this approach. In the Nutrition Surveillance Project implemented by Helen Keller International in 2000, the frequency of consumption, in seven days preceding an interview, of four nutrient-rich foods (i.e. egg, fish, green leafy vegetables and lentils) was collected bi-monthly for over 51 000 rural children aged 12–59 months. Fish was the most frequently eaten food, vegetables and lentils were eaten on fewer than two days, and more than 60 percent of children had not eaten egg. Also, other household members rarely ate egg, even though more than 90 percent of households reported having poultry (HKI, 2002). A similar food frequency consumption pattern was recorded in mothers of children under five years of age, in rural Bangladesh in 2005. Fish was the second most frequently consumed food, after rice, followed by milk, lentils, green leafy vegetables, egg, red/orange/yellow vegetables and fruits, chicken and meat, in descending order of frequency of consumption (J. Waid, personal communication, February 2011).

In a very successful small-scale poultry production intervention, egg and poultry production was reported in a sample of intervention and non-intervention households. Expectedly, the production of chicken and egg was significantly higher in the intervention compared to the non-intervention households. Consumption data from one woman and one girl child under five years of age from each household showed that the intakes of egg and chicken were similar in all households; however, the intake of small fish was significantly higher in the intervention households compared to the non-intervention households. The women ranked small fish as the second most preferred food to buy with increased household income. Fruits ranked first, leafy vegetables, third and two animal-source foods, milk and beef, fourth and fifth, respectively (Nielsen, Roos and Thilsted, 2003). These data show that in Bangladesh and perhaps other developing countries with fish as a common food, there is great scope to increase the consumption of this frequently consumed animal-source food, rich in multiple nutrients, including micronutrients, with high bioavailability, provided it is readily accessible.

Aquaculture from a nutritional perspective

In response to declining fish availability, the Government of Bangladesh, together with development partners embarked on projects to initiate aquaculture, with the aim of increasing fish production for sale, and thereby fish consumption. In the last 25 years, pond aquaculture, based on well-known production techniques of carp polyculture has flourished. The Mymensingh Aquaculture Extension Project (MAEP), with support from Danish International Development Assistance (Danida) was very successful, reaching 40 000 households, from 1989 to 1999. Large fish belonging to the carp species: silver carp – the dominant species, common carp (*Cyprinus carpio*), and the indigenous carps, “rui” and “mrigal” (mrigal carp, *Cirrhinus cirrhosus*) were produced in small homestead ponds. Before stocking of the carps into the ponds, eradication of self-recruiting species, the majority being SIS was practiced by repeated netting, dewatering and the use of a piscicide (rotenone), based on the rationale that there is competition between stocked and native fish. The amount of fish (measured as raw, whole fish) in the culture ponds rose to 1.0–3.7 tonnes/ha/year, compared to 0.5 tonnes/ha/year in ponds with traditional management practices (Roos *et al*., 2007d).

Recognizing the above-described importance of SIS in the diets of rural Bangladeshis and the potential for supplying the limiting essential nutrients vitamin A, calcium, iron and zinc, a number of production trials with polyculture of carps and SIS have been conducted in small, seasonal and perennial ponds. In the first trials, carps were stocked without the eradication of SIS; in later studies, without eradication of SIS, carps were stocked with “mola”, as well as the giant river prawn (*Macrobrachium rosenbergii*) (Kohinoor *et al*., 1998, 2001; Kohinoor, 2000; Roos, 2001; Wahab, Alim and Milstein, 2003; Roos, Islam and Thilsted., 2004; Kadir *et al.,* 2006; Milstein, Kadir and Wahab, 2008; Milstein *et al.,* 2009). No significant difference in total fish production was seen between ponds stocked with “mola” and those without “mola”. However, the nutritional quality of the total fish production improved considerably. “Mola” reproduced in the pond several times in the production season, and in order to avoid overpopulation, bi-weekly partial harvesting of “mola” was practiced. In one study, the use of the harvested “mola” was recorded; 47 percent was consumed in the household and the remainder was sold (Roos, Islam and Thilsted, 2003a).

This production technology of carps and “mola” in pond polyculture in Bangladesh has gained wide acceptance by the government and development partners working with rural populations. A breakthrough was made in 2004 when the Ministry of Fisheries and Livestock issued a directive to project directors in the fisheries extension services to implement carp/”mola” pond poyculture throughout rural Bangladesh. Also, non-governmental organizations (NGOs) working with poor, rural households in Bangladesh are implementing this technology. Furthermore, it has been successfully introduced in the Sundarbans, West Bengal, India[2], as well as in Terai, Nepal, with initial assistance from the Faculty of Fisheries, Bangladesh Agricultural University. In addition, on the dykes of ponds, seasonal, micronutrient-rich vegetables are being grown with the use of the nutrient-rich water and soil from the ponds. It is estimated that a small production of 10 kg/pond/year of the vitamin A-rich SIS, “mola”, in the four million small, seasonal ponds in Bangladesh can meet the recommended vitamin A intake of over 6 million children. As vitamin A is stored in the body, a high seasonal intake can be utilized to build up reserves to meet constant tissue needs. Aquaculture technologies combining production of large fish with nutrient-rich small fish are highly applicable in other developing countries in Africa and Asia with inland water resources and habitual small fish consumption.

In order that micronutrient-rich small fish production can become an integral part of aquaculture, priority must be given to conservation and management of common fisheries resources, including inland waterbodies such as beels (floodplain depressions and lakes) and fish migration routes. Work carried out on the reestablishment of fish migratory routes to floodplains resulted in restoration of fish habitats, a five-fold increase in total fish production and a doubling of the proportion of fish (mainly SIS) caught that was consumed by the landless and small farmers after restoration (CNRS, 1996).

Aquaculture is also being practiced in seasonal floodplains. Stocking of carp fingerlings and management, including enforcement of fishing regulatory measures in a large beel (40 ha) in northwest Bangladesh resulted in a total fish production of over 25 tonnes in six months, of which 45 percent were non-stocked fish, mainly SIS (Rahman *et al.*, 2008). Aquaculture in rice fields is also being done. In studies on the different combinations of fish species, both large fish and SIS, in rice-fish culture, higher yields of rice grain and straw were reported in rice fields with fish compared to those without fish; and the SIS, “dhela” was reported to be well-suited for culture (Dewan *et al.,* 2003). Trials have also been carried out with rice, giant river prawn and “mola” culture in rotation as well as concurrently (Wahab *et al.,* 2008, Kunda *et al.,* 2008, 2009).

2 Source: Oral presentation given by M. Kunda, B. Mahakur, S. Sengupta, M.A. Wahab, S.H. Thilsted. and N. Roos. *Introducing the nutrient dense, small indigenous fish species, mola* (Amblypharyngodon mola) *in pond aquaculture with carps and prawn in the Sundarbans region*, India. 8th Asian Fisheries Forum, 20–23 November 2007, Kochi, India.

Depending on geographical location and season, these culture practices can increase productivity as well as the nutritional quality of the combined rice and fish production.

The above studies show that aquaculture has been successfully linked to the promotion of improved human nutrition and health in Bangladesh. Years of work in interdisciplinary research, participatory field trials and studies, laboratory analyses, documentation and publication of research results, information sharing between professionals in multiple sectors, in particular fisheries and nutrition and health, dissemination, capacity building, awareness, advocacy and policy-making have led to this success.

Firstly, the recognition that data collection at the fish species level of fish produced and caught, both non-stocked and stocked, and consumed, at the intra-household level was crucial for attempts to exploit the potential of aquaculture to improve nutrition and health, especially of the rural poor. A lot of interest was generated with documenting unequivocally that calcium from the bones of SIS was as bioavailable as that from milk, commonly regarded as the best source of calcium. Eliminating the use of rotenone to eradicate SIS was easy to implement as soon as the farmers were convinced that carp production is not reduced by leaving the SIS in the pond and stocking "mola". Rotenone accounted for 10 percent of the total production costs, and the farmers are aware that the pond is not a closed system and that SIS also enter the pond, for example, with duckweed used for feeding. Establishing that "mola" breeds in the pond and frequent, partial harvesting of small amounts is necessary to control the stock was instrumental in increasing "mola" consumption – as this harvesting technique favours home consumption. On the other hand, the majority of carps are generally harvested all at once and sold immediately to a wholesaler at the end of the production season, five months or more after stocking. This harvesting pattern does not favour frequent home consumption.

In addition to the direct contribution of aquaculture in supplying essential vitamins and minerals, small-scale aquaculture which involves women is shown to have positive effects through increased household income, as well as the many factors related to women's empowerment, including decision-making; access to economic, social and political resources; knowledge, training, education and mobility. These positive effects have the potential to benefit nutrition and health.

However, as nutrition is also determined by factors other than food and nutrients, care and health, for which women are generally responsible, it is important that the work load of women in aquaculture is taken into account. Participation of women in small-scale aquaculture in Bangladesh has shown to increase their work load, especially with feeding of fish, feed preparation and harvesting

(Shirajee, Salehin and Ahmed, 2010). At the same time, the participation of women, especially in small-scale aquaculture opens a natural entry to reaching women in their homes, with behaviour change communication and adoption of, for example, improved infant and young child feeding practices, including care, hygiene and sanitation.

Conclusions

This paper describes the missed opportunity which aquaculture can embrace for nutrient-rich small fish to play a substantial role in improving nutrition and health. This important benefit of aquaculture has been greatly overlooked. Small fish is a source of multiple essential nutrients, including vitamins and minerals which are not found in the staple food and are in inadequate amounts in the diets of the rural poor. However, SIS should not only be viewed as supplying essential nutrients, but first and foremost, as an irreplaceable animal-source food; an integral part of the everyday diet of rural populations. In cementing the role of SIS, firm steps must be taken to stop the use of the terms, “low value”, “trash fish” and “weed fish” for SIS, as well as to qualify the term “high value” (used for large fish), which refers specifically to “high market value”, in terms of price and not nutritional value. Aquaculture also offers scope for the development and implementation of nutrition-sensitive value chain activities, for example, in processing and marketing.

To make better use of the potential of aquaculture to improve nutrition and health, the WorldFish Center, Bangladesh has recently initiated a project “Linking fisheries and nutrition: promoting innovative fish production technologies in ponds and wetlands with nutrient-rich small fish species in Bangladesh”, with financial support from the International Fund for Agricultural Research (IFAD). The major components include production of carps and “mola” in household ponds and wetlands, integrated with the promotion of SIS consumption by women, in particular pregnant and lactating women, and young children from six months of age, as well as behaviour change communication and adoption of improved practices of infant and young child feeding. This project builds on concepts of linking agriculture and nutrition and health, incorporated in, for example, the Consultative Group for International Agricultural Research (CGIAR) Research Programmes, in particular 1.3 “Harnessing the development potential of the aquaculture agriculture systems for the poor and vulnerable”, 3.7 “More meat, milk and fish by and for the poor” and 4 “Agriculture for improved nutrition and health”, as well as the United States Agency for International Development (USAID)-funded initiative “Feed the future”. Aquaculture can also contribute to the Scaling up Nutrition (SUN) movement, in providing micronutrient-rich SIS which can be included in complementary foods for young children. In the project, WinFood, in rural Cambodia, a weaning food made of rice and two small fish, “trey changwa plieng” and “trey sloeuk russey” (*Paralaubuca typus*), with a high fat content (12 g fat/100 g raw, edible parts) is being fed to children, from six months of age for nine months. Indicators of nutritional status are being measured.[3]

The recent hikes in global food prices place a great responsibility on aquaculture to ensure that SIS are available and affordable to the poor. Poor households must struggle harder to meet their need for staple foods, in an effort to ward off hunger. As a consequence, less money is available for spending on nutrient-rich foods, such as animal-source foods, vegetables and fruits, leading to decreased micronutrient intakes and high prevalence of hidden hunger.

In order that activities and investments in aquaculture can be focused and targeted to improving nutrition and health, research work in specific areas must be carried out. Further data on the bioefficacy and bioavailability of nutrients from fish, as well as on intra-household seasonal consumption at the species level, nutrient analyses, and the cleaning, processing and cooking methods of small fish are needed. Advocacy, awareness and nutrition education on the role small fish can play in increasing diet diversity and micronutrient intakes must be strengthened at all levels. Measures to develop and implement sustainable, low-cost, innovative technologies for greater management, conservation, production, preservation, availability and accessibility of SIS must be undertaken. In addition, an analysis of the cost-effectiveness of micronutrient-rich small fish species in combating micronutrient deficiencies should be carried out using the DALYs framework.

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[3] Source: Poster presentation by N. Roos, M. Nurhasan, M., Bun Thang, J. Skau, F. Wieringa, Kuong Khov, H. Friis, K.F. Michaelsen and C. Chamnan,. *WinFood Cambodia: improving child nutrition through improved utilization of local food.* Biodiversity and sustainable diets: united against hunger. Symposium hosted by Bioversity International and FAO, 3–5 November 2010, Rome, Italy.

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