# Linking human nutrition and fisheries: Incorporating micronutrient-dense, small indigenous fish species in carp polyculture production in Bangladesh

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## Abstract

***Background.*** *Fish and fisheries are important for the livelihoods, food, and income of the rural population in Bangladesh. Increased rice production and changing agricultural patterns have resulted in a large decline in inland fisheries. Implementation of carp pond polyculture has been very successful, whereas little focus has been given to the commonly consumed small indigenous fish species, some of which are rich in vitamin A and minerals, such as calcium, iron, and zinc, and are an integral part of the rural diet.*

***Objective.*** *The overall objective of the research and capacity-building activities described in this paper is to increase the production, accessibility, and intake of nutrient-dense small indigenous fish species, in particular mola (*Amblypharyngodon mola*), in order to combat micronutrient deficiencies. The large contribution from small indigenous fish species to recommended intakes of vitamin A and calcium and the perception that mola is good for or protects the eyes have been well documented.*

***Methods.*** *An integrated approach was conducted jointly by Bangladeshi and Danish institutions, linking human nutrition and fisheries. Activities included food-consumption surveys, laboratory analyses of commonly consumed fish species, production trials of carp–mola pond polyculture, teaching, training, and dissemination of the results.*

***Results.*** *No decline in carp production and thus in income was found with the inclusion of mola, and increased intake of mola has the potential to combat micronutrient deficiencies. Teaching and training of graduates and field staff have led to increased awareness of the role of small indigenous fish species for good nutrition and resulted in the promotion of carp–mola pond polyculture and research in small indigenous fish species. The decline in accessibility, increase in price, and decrease in intake of small indigenous fish species by the rural poor, as well as the increased intake of silver carp (*Hypophthalmichthys molitrix*), the most commonly cultured fish species, which is poor in micronutrients and not preferred for consumption, are being addressed, and some measures taken by inland fisheries management have been discussed.*

***Conclusions.*** *The successful linking of human nutrition and fisheries to address micronutrient deficiencies has relevance for other countries with rich fisheries resources, such as Cambodia and countries in the Lake Victoria region of Africa.*

**Key words:** Small indigenous fish, aquaculture, fisheries, micronutrient deficiency, human nutrition, Bangladesh

## Background

Fish and rice dominate the livelihoods and diet of rural Bangladeshis to such an extent that the old proverb "mache bhate bangali" (fish and rice make a Bengali) continues to be quoted. Together with the staple rice and small amounts of vegetables, fish constitutes the everyday diet of the rural poor, especially in the fish production season. Moreover, fish and fisheries are important for the income of many rural poor, providing the main source of income to about 2 million households that either fish for a living or are involved in related trades [1]. Many more households catch freshwater fish for a part-time income and for food [2, 3]. In rural communities close to water, 87% of households catch fish for a part of the year [4].

The floodplains, rivers, streams, canals, beels (flood-

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plain depressions and lakes), and ponds are rich ecosystems for the more than 260 species of freshwater fish found in Bangladesh. About 140 species are classified as small indigenous fish species, with a maximum length of less than 25 cm [5]. The floodplains that comprise over half of the country are inundated annually and during the monsoon (July–October) and postmonsoon periods provide an ideal habitat for the wide variety of wild fish species, especially small indigenous fish species. In the dry season (November–March), the floodplains are cultivated with rice.

### Fish in human nutrition in Bangladesh

As in many countries, the official statistics and data for fish production in Bangladesh that are used as a proxy for consumption are based solely on those collected by governmental agencies from large landing sites and markets. This data fail to include the major part of the total fish production, consisting of fish, in particular small indigenous fish species, that are caught, sold, and consumed by the rural population. In the official statistics, very small values, which are gross underestimations, are reported for the group “trash” or “weed” fish, to which small indigenous fish species belong. There has been very little focus on these fish in the fisheries sector, and no connection has been made between their capture and production, intakes, and seasonal variations in their intakes.

The importance of fish in the Bangladeshi diet was documented in the first food-consumption survey carried out in 1962–64, surveys in rural areas in 1975–76 and 1981–82 [6], and a national survey in 1995–96 [7]. In the 1981–82 rural survey, the mean total fish intake was reported as 23 g of raw, whole fish per capita per day. The total food intake was 763 g of raw food per capita per day, of which 60% was rice, 30% vegetables, and 6% animal foods, with fish making up 53% of the animal foods. Even though data were not collected at the species level, it was generally accepted in the nutrition sector that small indigenous fish species made up the greater part of the fish intake, especially among the rural poor, and there were large seasonal variations in the intake of small indigenous fish species.

Some studies were conducted on the nutrient contents of small indigenous fish species in the 1970s and 1980s. It was reported that some small species contain high levels of protein, vitamins, iron, calcium, and other minerals; in particular, mola (*Amblypharyngodon mola*), darkina (*Esomus danricus*), and dhela (*Osteobrama cotio cotio*) contain high levels of vitamin A compounds in the form of dehydroretinol ($A_2$) and retinol ($A_1$) (determined by a colorometric method) [8–14].

In Bangladesh, vitamin A deficiency, iron-deficiency anemia, and zinc deficiency continue to be major public health problems. Among preschool children, 30.8% have vitamin A deficiency [15] and 55% iron-deficiency anemia [16]. Bangladesh is classified as having a high risk of zinc deficiency on the basis of indirect indicators [17]. A marked decrease in night-blindness in children since the 1970s has been documented [18]. In 1973 high-potency vitamin A capsule supplementation of preschool children was initiated to combat vitamin A deficiency, and in 1988 Helen Keller International initiated home-gardening projects. Even though there was no focus on the role of fish in combating vitamin A deficiency, it has been reported that in the late 1970s, there were radio and television spots informing the general public of the health and nutritional values of consuming mola and dhela as rich sources of vitamin A. It is, however, also reported that in the drive to make the vitamin A supplementation program a success, attention was drawn away from the role that vitamin A–rich small indigenous fish species could play.

### Changes in fish capture and production leading to improved pond aquaculture in Bangladesh

It has been recognized that capture fisheries in Bangladesh are in decline, although the magnitude of the problem has been grossly underestimated. Since the Green Revolution, rice production has increased tremendously in Bangladesh, meeting the needs of the growing population. This success has taken place as a result of many changes in the overall agricultural production and the use of land and water. More areas have been brought under rice production, high-yielding rice varieties that require little water are grown, large areas have been drained and protected by flood control embankments, and the use of irrigation and pesticides has expanded greatly. These changes have been at the expense of fish; the areas of inland water and inundation have decreased, thereby reducing the habitats for fish and cutting off migratory routes from breeding grounds [3].

There have been few efforts to address the decline in small indigenous fish species. In 1987, the Bangladesh Fisheries Research Institute (BFRI) initiated programs to develop breeding and culture techniques for some small indigenous fish species but without focus on the commonly consumed and nutrient-dense species. The possibility of culturing some small indigenous fish species, including the vitamin A–rich mola and dhela, in shallow, small water bodies was explored in a UNICEF-supported project, but the efforts did not receive wide acceptance, perhaps because the rapid rate of decline in the availability of freshwater fish was not considered to be a matter of grave concern [19]. In the 1980s, the production potential of few small indigenous fish species, including mola, in miniponds was also reported [20].

Because of the concern that fish availability was declining as a result of the rapid population growth and urbanization, the Government of Bangladesh, through the Department of Fisheries, Ministry of Fisheries and Livestock, and in collaboration with partners such as the Danish International Development Assistance (Danida), the Department for International Development (of the United Kingdom Government) (DFID), the World Bank, and the WorldFish Center (formerly the International Center for Living Aquatic Resources Management [ICLARM]) embarked on projects to initiate aquaculture with the aim of increasing fish production for sale and thereby consumption. Pond aquaculture, based on well-known production techniques of carp polyculture, began to flourish [21].

With support from Danida, the Mymensingh Aquaculture Extension Project (MAEP) was initiated in 1989 and implemented by the Department of Fisheries. Well-trained fisheries extension officers, both women and men, making frequent household visits on their motor bikes, provided credit, trained small farmers in polyculture in small homestead ponds, and closely supervised and monitored production and sale. About 85% of the fish produced in pond polyculture are exotic carp species, such as silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio*), and indigenous species, such as rui (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*), with silver carp being the dominant species [22]. Locally available, inexpensive, low-grade feeds and fertilizers (rice bran, banana leaf, cow dung) and chemical fertilizers (urea and phosphate) are used. Eradication of the self-recruiting fish species, the majority of which are small indigenous fish species, was practiced by repeated netting, dewatering, and the use of a piscicide, rotenone, based on the rationale that there would be competition between the cultured and the native fish.

The MAEP was considered a huge success; more than 40,000 farmers in seven districts received training in the period from 1989 to 1999. The amount of fish produced in cultured ponds rose to 1.0 to 3.7 metric tons of raw, whole fish/hectare/year, as compared with about 0.5 metric tons in noncultured ponds. This drastic change in fish production, especially the large increase in silver carp production, has important implications for the availability and nutritional contribution of fish for the rural poor.

### Initiation of a project to link human nutrition to fisheries in Bangladesh

Building on the success of the MAEP in Bangladesh and the longstanding involvement of Danida in development projects in Bangladesh, with emphasis on the rural poor, financial support was obtained from the Danish Bilateral Program for Enhancement of Research Capacity in Developing Countries (ENRECA) in late 1993, to initiate a 4-year capacity-building and research project entitled "Food and nutrition security in Bangladesh: energy and micronutrient availability in rice-based diets." The coordinating institution was the Department of Human Nutrition (formerly the Research Department of Human Nutrition) of the Royal Veterinary and Agricultural University (KVL), Denmark, and the partner institutions in Bangladesh were the Institute of Nutrition and Food Science of the University of Dhaka, the Bangladesh Rice Research Institute, and the Faculty of Fisheries of Bangladesh Agricultural University (BAU). ENRECA is funded by the Council for Development Research, Danida, Ministry of Foreign Affairs of Denmark. Until the present date, financial support from Danida has continued to the Department of Human Nutrition, KVL, and the Faculty of Fisheries, BAU, for further research and capacity-building activities within the areas of fisheries production and management and the importance of fish for food and nutrition security in Bangladesh.

## Objective

The overall objective of the research and capacity-building activities is to increase the production, accessibility, and intake of nutrient-dense small indigenous fish species in order to combat micronutrient deficiencies among women and children in rural Bangladesh.

Through an integrated approach of research and capacity-building at Bangladeshi and Danish institutions in the fields of food science, human nutrition, and fisheries, the main specific objectives included the following:

- To establish the importance of small indigenous fish species in the everyday diet of the rural poor and the contribution of small indigenous fish species to the intakes of micronutrients;
- To investigate the perceptions of fish species;
- To identify the commonly consumed, nutrient-dense small indigenous fish species in rural households;
- To analyze the commonly consumed, nutrient-dense small indigenous fish species for their vitamin and mineral content;
- To conduct studies on the bioavailability of calcium in small indigenous fish species;
- To conduct trials of carp–mola polyculture in ponds at the BAU and also in ponds belonging to small farmers;
- To study the biology, breeding, feeding, and management of commonly consumed, nutrient-dense small indigenous fish species;
- To include the study of small indigenous fish species in the curriculum at the Faculty of Fisheries, BAU;
- To train extension workers, field staff, scientists, and farmers in carp–mola pond polyculture;
- To disseminate information about the nutritional importance of small indigenous fish species for

the rural poor and carp–mola pond polyculture in Bangladesh.

## Methods

The methods used to fulfil some of the main specific objectives are described below.

### Food-consumption surveys and analysis of data

We reanalyzed the data from a small consumption survey conducted in a village in the Manikganj District in December 1991–January 1992 to calculate the intakes of small indigenous fish species and all other fish species, termed "large fish" [23]. We conducted consumption studies in the Manikganj village, a double-cropped rice, flooded area, using traditional farming practices, and in a village in the Mymensingh district, a triple-cropped nonflooded area, using modern farming practices; both villages were included in the Nutrition Survey of Rural Bangladesh 1981–82 [6], in two seasons with respect to rice production, October–November 1995 (the lean season) and January–March 1996 (the peak season) [24, 25]. The method used was 24-hour food weighing at the individual level, once per season. Fish intake was recorded at the species level. In collaboration with the International Food Policy Research Institute, we analyzed data on fish intake at the species level from a consumption study conducted in Mymensingh District in 1996/97, using a 24-hour recall method at the individual level, once per season [26]. A study was conducted in 84 rural households in Kishoreganj District in three rounds (July 1997, October 1997, and February 1998) in which household intake of fish at the species level was measured by recall interviews over a 5-day period, once per round, with the aid of food models, cardboard models for large fish, and weighed quantities of mixed small indigenous fish species [27, 28 ].

### Laboratory analyses of nutrients in fish samples

Determination of the nutrient content in samples of selected, commonly consumed small indigenous fish species and large fish was carried out, with a focus on vitamin A, calcium, iron, and zinc. Samples of raw, whole fish; raw, cleaned fish; different parts of raw, cleaned fish; raw, edible parts (excluding plate waste); dried small indigenous fish species; and semi-fermented small indigenous fish species were used. Vitamin A compounds (all-*trans* dehydroretinol, 13-*cis* dehydroretinol, all-*trans* retinol, 13-*cis* retinol, and β-carotene) were determined by high-performance liquid chromatography (HPLC) [29, 30] and calcium, iron, and zinc by atomic absorption spectrometry [31] at laboratories in Denmark (**tables 2** and **3**).

The cleaning of the fish samples was done by village women using their traditional methods, which varied depending on the fish species, the size of the fish, and individual habits. Generally, the viscera of the small indigenous fish species were removed and sometimes also the fins, gills, and scales. Plate waste was also estimated and used to correct for the calcium content of the fish species [28]. For many small indigenous fish species, the raw, cleaned parts, with bones, were cooked and nearly all bones were also eaten, resulting in very little plate waste. In some small indigenous fish species, a few hard bones formed the plate waste, depending on the size of the fish, the preparation, and the person eating the fish. For many large fish, all bones were discarded during eating, forming the plate waste.

### Production trials

Before the initiation of this project, we requested the MAEP to carry out a small production trial in which rotenone was not applied and the native fish were left. Eight ponds were studied, and the results indicated that the carp production was not hampered and there was an extra production of small indigenous fish species, which the households consumed. Based on these results, the positive perceptions of mola, information from the farmers that mola thrive in ponds, and, most importantly, the high content of vitamin A compounds in mola, we decided to focus our research activities on mola.

A number of polyculture production trials of carp with small indigenous fish species have been conducted in experimental ponds at the BAU as well as farmers' ponds, using varying stocking rates; combinations of fish species, including both carp and small indigenous fish species; feeding, fertilizer, and manure application regimens; and harvesting frequencies [27, 32–36]. Studies have also been conducted on the reproduction, feeding, and biology of mola, as well as the management, collection, and transportation of mola brood stock. Surveys were conducted on the handling, transportation, and marketing of small indigenous fish species in 10 landing centers in three districts, as well as on the prices of fish species in local markets. In addition, small studies have been conducted on the introduction of different combinations of fish species, both small indigenous fish species and large fish, in rice fields [37].

### Teaching and training

The study of small indigenous fish species, including their nutritional value, has been incorporated in the B.Sc. and M.Sc. programs at the Faculty of Fisheries, BAU. In the M.Sc. program at the Department of Human Nutrition, KVL, Denmark, the importance of small indigenous fish species for food and nutrition security in Bangladesh has been incorporated in one course. Project components have formed the basis for studies and fieldwork within fisheries and human nutrition, resulting in B.Sc., M.Sc., and Ph.D. theses by students from Bangladesh and Denmark. Five 2-week biannual training courses and four 2-day follow-up courses in food and nutrition security in Bangladesh were held for field personnel from governmental departments, United Nations agencies, and nongovernmental organizations (NGOs) within the fields of agriculture, health, and nutrition. Guest lectures were given and case studies conducted on the importance of small indigenous fish species for food and nutrition security in Bangladesh. About 100 participants attended the training courses, and in the follow-up courses, the carp–mola pond polyculture and nutrition education programs that were initiated were discussed.

### Dissemination and collaboration

Through field trials, meetings, discussions, and participation in national workshops and seminars with the rural population as well as the staff of governmental, national, and international NGOs, bilateral and UN agencies, and research institutions, primarily in the areas of agriculture and human nutrition, we have disseminated information on our research and capacity-building activities and results. We have presented our results at national, regional, and international conferences and workshops, for example, the International Congress on Nutrition and the Asian Fisheries Forum, and are often invited to give presentations in forums related to rural development and public health. Our work has been published in a number of relevant national, regional, and international journals. Through collaboration with regional and international institutions, including those of the Consultative Group on International Agricultural Research (CGIAR), our activities and results have been disseminated beyond Bangladesh.

## Results

Selected results of our research and capacity-building activities that exemplify the linking of human nutrition and fisheries in Bangladesh are presented below.

### Fish consumption

In the small food-consumption survey in the Manikganj village in December 1991–January 1992 [23], we found that small indigenous fish accounted for 72% of the total fish intake, a much larger proportion than that of large fish. Further food-consumption surveys [24–27] confirmed that small indigenous fish accounted for a larger proportion of fish intake than large fish, especially by poor households, as well as confirming the seasonal variations in intakes (**table 1**). Total fish

TABLE 1. Fish intake in Bangladesh from selected studies

| Location | Year | Season | Small fish[a]—mean ± SD (median) g/capita/day | Large fish[b]—mean ± SD (median) g/capita/day | Total fish—mean ± SD (median) g/capita/day | Method | Ref. |
|---|---|---|---|---|---|---|---|
| Rural Bangladesh | 1962–64 | | | | 28[c] | 700 hh 14 locations, 24-h food weighing | 38 |
| Rural Bangladesh | 1975–76 | | | | 23[c] | 750 hh, 12 locations, 24-h food weighing | 8 |
| Rural Bangladesh | 1981–82 | | | | 23[c] | 600 hh, 12 locations, 24-h food weighing | 6 |
| Tangail | 1992[d] | | | | 12 | 520 hh, interview | 39 |
| Surma-Kushiya Floodplains | 1992 | | | | 18 | | |
| Singra | 1992 | | | | 22 | | |
| Matlab | 1992 | | | | 34 | | |
| Manikganj | 1991–92 | Dec–Jan | 13 ± 19 (5)[e] | 5 ± 14 (0)[e] | 18 ± 22 (12)[e] | 119 hh, 24-h food weighing | 23 |
| Manikganj | 1995 | Oct–Nov | 28 ± 45 (8)[e] | 29 ± 51 (0)[e] | 57 ± 62 (42)[e] | 152 hh, 769 individuals, 24-h food weighing | 24, 25 |
| | 1996 | Jan–Mar | 25 ± 47 (0)[e] | 12 ± 36 (0)[e] | 37 ± 56 (19)[e] | 145 hh, 717 individuals, 24-h food weighing | |

*continued*

TABLE 1. Fish intake in Bangladesh from selected studies *(continued)*

| Location | Year | Season | Small fish[a]—mean ± SD (median) g/capita/day | Large fish[b]—mean ± SD (median) g/capita/day | Total fish—mean ± SD (median) g/capita/day | Method | Ref. |
|---|---|---|---|---|---|---|---|
| Kishoreganj | 1997 | Jul | 28 ±26 (21)[f] | 10 ± 17 (5)[f] | 37 ± 33 (27)[f] | 84 hh, 5-day fish recall interview | 27, 28 |
| | 1997 | Oct | 65 ± 55 (45)[f] | 18 ± 25 (7)[f] | 82 ± 65 (64)[f] | | |
| | 1998 | Feb | 38 ± 40 (25)[f] | 16 ± 18 (12)[f,e] | 55 ± 48 (42)[f] | | |
| Mymensingh | 1995 | Oct–Nov | 14 ± 33 (0)[e] | 24 ± 38 (6)[e] | 38 ± 47 (25)[f] | 152 hh, 765 individuals, 24-h food weighing | 24, 25 |
| | 1996 | Jan–Mar | 12 ± 22 (0)[e] | 20 ± 34 (0)[e] | 32 ± 37 (24)[e] | 146 hh, 729 individuals, 24-h food weighing | |
| Mymensingh | | | | | | | |
| Low income | 1996 | Jun–Sep | 17 ± 21 (8)[g] | 9 ± 18 (0)[g] | 26 ± 26 (21)[g] | 104 hh, 24-h recall | 26 |
| Medium income | | | 22 ± 26 (13)[g] | 14 ± 22 (2)[g] | 35 ± 31 30)[g] | 104 hh, 24-h recall | |
| High income | | | 25 ± 34 (11)[g] | 17 ± 27 (3)[g] | 42 ± 40 (31)[g] | 105 hh, 24-h recall | |
| Low income | 1996 | Oct–Dec | 26 ± 41 (18)[g] | 6 ± 12 (0)[g] | 32 ± 42 (25)[g] | 104 hh, 24-h recall | |
| Medium income | | | 23 ± 2 (19)[g] | 19 ± 49 (2)[g] | 42 ± 54 (34)[g] | 104 hh, 24-h recall | |
| High income | | | 25 ± 24 (19)[g] | 18 ± 25 (4)[g] | 43 ± 32 (38)[g] | 105 hh, 24-h recall | |
| Low income | 1997 | Feb–May | 12 ± 17 (4)[g] | 8 ± 13 (2)[g] | 20 ± 21 (14)[g] | 104 hh, 24-h recall | |
| Medium income | | | 13 ± 19 (4)[g] | 12 ± 18 (3)[g] | 25 ± 25 (19)[g] | 104 hh, 24-h recall | |
| High income | | | 14 ± 19 (6)[g] | 15 ± 21 (3)[g] | 29 ± 26 (24)[g] | 105 hh, 24-h recall | |
| Low income | 1997 | Jun–Sep | 21 ± 24 (13)[g] | 9 ± 16 (0)[g] | 30 ± 27 (23)[g] | 104 hh, 24-h recall | |
| Medium income | | | 30 ± 38 (18)[g] | 11 ± 17 (3)[g] | 41 ± 38 (30)[g] | 104 hh, 24-h recall | |
| High income | | | 28 ± 31 (21)[g] | 13 ±25 (0)[g] | 41 ± 37 (32)[g] | 105 hh, 24-h recall | |
| Kapasia | | | | | | | |
| Small farm | 1998–99 | Aug–Jul | | | 83[g] | 20 hh, 84 days 24-h fish weighing | 40 |
| Medium farm | 1998–99 | Aug–Jul | | | 85[g] | 36 hh, 84 days 24-h fish weighing | |
| Large farm | 1998–99 | Aug–Jul | | | 96[g] | 12 hh, 84 days 24-h fish weighing | |
| Dinajpur (Ashurar Beel) | 1999 | Jan–May | 8 ± 7 (6)[g] | 5 ± 8 (3)[g] | 13 ± 11 (11)[g] | 90 hh, 24-h food weighing, 7 days per month | |
| | | Jun–Sep | 24 ± 19 (20)[g] | 2 ± 4 (0)[g] | 26 ± 19 (23)[g] | | |
| | | Oct–Dec | 29 ± 17 (25)[g] | 5 ± 7 (3)[g] | 34 ± 19 (31)[g] | | |
| Kishoreganj (Kali Nadi) | 1999 | Jan–May | 18 ± 9 (16)[g] | 8 ± 7 (6)[g] | 26 ± 14 (23)[g] | 90 hh, 24-h food weighing, 7 days per month | |
| | | Jun–Sep | 20 ± 10 (19)[g] | 9 ± 8 (7)[g] | 28 ± 13 (26)[g] | | |
| | | Oct–Dec | 28 ± 15 (25)[g] | 12 ± 12 (8)[g] | 40 ± 21 (36)[g] | | |

hh, households

*a.* Small fish are small indigenous fish species (SIS) [5]. In Thompson et al. [40], small fish include SIS, shrimp (except in Hamil Beel, Ashurar Beel, and Kali Nadi), and the following medium-sized fish: magur, rita, baila, bara baim, bhangon, and kaklia.

*b.* Large fish include all fish species other than SIS.

*c.* Raw, edible parts.

*d.* Drought year.

*e.* Raw, cleaned fish.

*f.* Raw, edible parts. Corrected for cleaning and plate waste: 13% mean for SIS; 22% (8% plate waste) mean for large fish.

*g.* Raw, whole fish.

Source: Adapted from Thompson et al. [3].

intake as well as the intake of small indigenous fish species and large fish from other surveys conducted in different regions of Bangladesh are also shown in **table 1**.

Data on the intake of individual fish species at the household level were obtained in the above-mentioned study conducted in Kishoreganj District [27]. The highest intake was recorded in October and the lowest in July (**table 1**). In total, 44 common names for fish and 2 common names for shrimp were recorded in the three rounds. Small indigenous fish species contributed 84% of the total fish intake (raw, edible parts), and 57% of the total fish intake was made up of five species: puti (*Puntius* sp.), silver carp, taki (*Channa punctatus*), baim/chikra (*Macrognathus aculeatus*, *Mastacembelus armatus*, *Mastacembelus pancalus*), and mola, in descending order of percentage. Puti, eaten both fresh and fermented, was the most commonly consumed species, accounting for 26% of the total fish intake, calculated as raw, edible parts, covering 10 *Puntius* species, with 3 species (*Puntius sophore*, *P. chola,* and *P. ticto*) being the most common. The frequency of fish consumption, and in particular of small indigenous fish species, was high; all households consumed small indigenous fish species on at least one of the five days of recall, except for one household in July and two households in October, whereas one-third of the households did not consume large fish. The market was the most important source of fish, contributing 57% to 69% of the total fish intake in the three rounds, followed by fish caught by household members, accounting for 16% to 37% of total fish intake. Fish from the households' own ponds was a minor source [27, 28].

Fish prices in the local markets in Kishoreganj

TABLE 2. Categories of commonly consumed fish species according to vitamin A content

| Category | Vitamin A content[a] (RAE/100 g raw, cleaned parts) | Common name[b] | Scientific name |
|---|---|---|---|
| Very high | >1,500 | Mola | *Amblypharyngodon mola* |
| | | Chanda | *Parambassis baculis* |
| High | 500–1,500 | Dhela | *Osteobrama cotio cotio*[c] |
| | | Darkina | *Esomus danricus* |
| Medium | 100–500 | Chanda | *Parambassis ranga, Chanda nama* |
| | | Koi | *Anabas testudineus* |
| | | Tengra | *Mystus vittatus* |
| | | Taki | *Channa punctatus* |
| | | Chela | *Chela cachius* |
| Low | < 100 | Kachki | *Corica soborna* |
| | | Baim/Chikra | *Macrognathus aculeatus, Mastacembelus pancalus, Mastacembelus amatus* |
| | | Puti | *Puntius sophore, Puntius chola, Puntius ticto* |
| | | Gutum | *Lepidocephalus guntea* |
| | | Chapila | *Gudusia chapra* |
| | | Kolisha | *Colisa fasciatus* |
| | | Shing | *Heteropneustes fossilis* |
| | | Magur | *Clarias batrachus* |
| | | Chata | *Colisa lalia* |
| | | Tilapia | *Oreochromis niloticus* |
| | | Mrigal | *Cirrhinus cirrhosus* |
| | | Rui | *Labeo rohita* |
| | | Silver carp | *Hypophthalmichthys molitrix* |
| | | Hilsha | *Tenualosa ilisha*[d] |

RAE, retinol activity equivalent

*a.* A single sample of some species and replicate samples of other species were analyzed.

*b.* The fish species are listed in order of decreasing vitamin A content.

*c.* One sample of dhela was analyzed in a minor study conducted at the Department of Human Nutrition, The Royal Veterinary and Agricultural University, Denmark, in 1993. Dhela was not available for sampling at the time when this study was conducted.

*d.* An alternative scientific name is *Hilsa ilisha.*

Source: Roos et al. [29].

District varied considerably: in the lean fish season of July they were nearly double the prices in the peak fish season of October. Puti and mixed small indigenous fish species were the cheapest fish in the markets. In general, large fish were more expensive than small indigenous fish species, with the exception of silver carp, which was as cheap as many small indigenous fish species. In July and October, the prices of small indigenous fish species were 45 and 17 BDT/kg of raw, whole fish, respectively, whereas the prices of large fish (excluding silver carp) were 55 and 33 BDT/kg raw, whole fish, respectively (44.8 BDT = US$1) [27].

### Content and bioavailability of nutrients in small indigenous fish species

In a small study of the nutrients in a few commonly consumed small indigenous fish species, it was found that the raw, edible parts of mola, darkina, and dhela had high contents of vitamin A compounds and calcium [41], whereas silver carp and rui (*Labeo rohita*) had very small amounts of these nutrients. Further analyses of other commonly consumed fish species were performed [42, 43]. The results showed that there were large variations between species in the amounts and proportions of dehydroretinol and retinol. This led to a more systematic screening of the content of vitamin A compounds in samples (some single, others replicate) of raw, edible parts of commonly consumed fish in rural Bangladesh. Based on the values obtained, the fish species were classified into four categories: very high, high, medium, and low vitamin A contents (**table 2**) [27, 29].

Analysis of different parts of mola showed that the eyes contained 53% of the total vitamin A and the viscera 39%. Since many small indigenous fish species are sun-dried in the peak fish production season, samples of sun-dried mola were analyzed for vitamin A content. The results showed that sun-drying destroyed nearly all the vitamin A (101 retinol activity equivalents [RAE]/100 g of sun-dried mola) [27, 29].

**Table 3** shows the contents of calcium, iron, zinc, and dry matter in samples of raw, cleaned parts of selected, commonly consumed small indigenous fish species and large fish species. All small indigenous fish species are very rich sources of calcium, whereas large fish have low calcium contents, after correction for plate waste. In addition, studies in both humans and rats have shown that the bioavailability of calcium in mola is as high as that in milk [44, 45]. One small indigenous fish species, darkina, was found to have higher contents of iron and zinc than the others, and the variations in the

TABLE 3. Mineral content in some commonly consumed Bangladeshi fish species

| Common name | Scientific name | N[a] | Mineral content per 100 g raw, cleaned parts—mean ± SD | | | | Dry matter (%) |
|---|---|---|---|---|---|---|---|
| | | | Ca (mg) | Ca[b] (mg) | Fe (mg) | Zn (mg) | |
| SIS | | | | | | | |
| Baim/ Chikra | *Macrognathus aculeatus, Macrognathus pancalus, Mastacembelus armatus* | 5 | 462 ± 56 | 203 ± 25 | 2.4 ± 0.4 | 1.2 ± 0.1 | 25 ± 1 |
| Chanda | *Parambassis ranga, Parambassis baculis, Chanda nama* | 5 | 955 ± 342 | 878 ± 314 | 1.8 ± 0.7 | 2.3 ± 0.6 | 24.3 ± 1.6 |
| Chapila | *Gudusia chapra* | 3 | 1,063 ± 51 | 786 ± 38 | 7.6 ± 5.3 | 2.1 ± 0.1 | 27 ± 3 |
| Darkina | *Esomus danricus* | 3 | 891 ± 357 | 775 ± 321 | 12.0 ± 9.1 | 4.0 ± 1.0 | 23 ± 3 |
| Kachki | *Corica soborna* | 2 | 476 ± 37 | 347 ± 34 | 2.8 ± 1.2 | 3.1 ± 0.5 | 16 ± 1 |
| Mola | *Amblypharyngodon mola* | 3 | 853 ± 8 | 776 ± 78 | 5.7 ± 3.7 | 3.2 ± 0.4 | 20 ± 1 |
| Puti | *Puntius sophore, P. chola, P. ticto* | 4 | 1,171 ± 216 | 784 ± 145 | 3.0 ± 0.9 | 3.1 ± 0.5 | 25 ± 1 |
| Taki | *Channa punctuatus* | 3 | 766 ± 183 | 337 ± 81 | 1.8 ± 0.4 | 1.5 ± 0.2 | 22 ± 1 |
| Tengra | *Mystus vittatus* | 2 | 1,093 ± 334 | 480 ± 147 | 4.0 ± 0.4 | 3.1 ± 0.8 | 26 ± 4 |
| Shrimp (chingri) | *Macrobrachium sp.* | 3 | 687 ± 23 | 687 ± 23 | 3.1 ± 2.2 | 1.5 ± 0.3 | 21 ± 2 |
| Large fish | | | | | | | |
| Mrigal | *Cirrhinus cirrhosus* | 2 | 960 ± 104 | 0 ± 0 | 2.5 ± 1.3 | 1.5 ± 0.1 | 24 ± 3 |
| Silver carp | *Hypophthamichyths molitrix* | 2 | 903 ± 361 | 37 ± 14 | 4.4 ± 1.8 | 1.4 ± 0.5 | 23 ± 2 |

SIS, small indigenous fish species
*a.* N = number of samples. A sample of SIS contained 10 to 300 fish; a sample of large fish contained 1 or 2 fish.
*b.* Calcium content corrected for plate waste [28].
Source: Adapted from Roos [27].

contents of iron and zinc between species seemed to be less than that of vitamin A [28, 29, 32].

## Production trials with small indigenous fish species

Data from one of the trials carried out with carp–mola pond polyculture are presented in **table 4** [27, 36]. A total of 59 small, seasonal ponds (mean size, 396 $m^2$; range, 212–850 $m^2$) belonging to poor rural households were used in the trial. Thirty-four ponds were used for carp–mola production, and before stocking rotenone was used to destroy the native fish. In addition to carp, mature mola (average weight, 1.6 g), collected from local ponds with natural stocks, were stocked. Twenty-five ponds were not treated with rotenone, and carp–native small indigenous fish species were produced. In all ponds, the average total fish production over a 7-month period was 2.87 tons/hectare (SD = 0.9, $n$ = 59). No significant difference in total fish production was seen between ponds stocked with mola and those without mola. It was shown that mola reproduces in ponds several times per season [46], and in order to avoid overpopulation, biweekly partial harvesting of mola was practiced. The use of the harvested mola was recorded; 47% of the total mola production in all ponds was consumed in the households, and the remainder was sold [28].

From the trials conducted in rice fields, it was found that the introduction of fish increased the availability of nutrients in the water and soil profoundly, resulting in higher yields of rice grain and straw [37]. Mola did not do well in the rice fields, exhibiting low growth and survival rates. However, the small indigenous fish species dhela and the large fish species thai sarpunti

TABLE 4. Fish production, stocking density, and inputs in carp–mola ponds

| Variable | $N$ | Mean | Minimum | Maximum | SD |
|---|---|---|---|---|---|
| Production period (days) | 34 | 217 | 181 | 238 | 14 |
| Pond area ($m^2$) | 34 | 394 | 234 | 680 | 107 |
| Carp production (metric tons/ha/season) | | | | | |
| Silver carp | 34 | 1.23 | 0.27 | 2.22 | 0.47 |
| Common carp or mrigal | 34 | 0.39 | 0.13 | 0.73 | 0.15 |
| Grass carp | 34 | 0.72 | 0.12 | 1.62 | 0.38 |
| Rui | 34 | 0.15 | 0.00 | 0.25 | 0.06 |
| Total carp production | 34 | 2.48 | 0.61 | 4.09 | 0.79 |
| SIS production (t/ha/season) | | | | | |
| Mola | 32 | 0.34 | 0.03 | 0.76 | 0.21 |
| Other SIS | 24 | 0.09 | 0.00 | 0.36 | 0.11 |
| Total SIS | 34 | 0.38 | 0.00 | 0.76 | 0.22 |
| Total fish production[a] | 34 | 2.84 | 0.71 | 4.42 | 0.84 |
| Stocking density (metric t/ha/season), see comment on p. 5 | | | | | |
| Silver carp (2 crops) | 34 | 7,526 | 3,310 | 9,826 | 2,152 |
| Common carp or mrigal | 34 | 1,991 | 862 | 3,702 | 511 |
| Grass carp | 34 | 1,998 | 0 | 4,407 | 638 |
| Rui | 34 | 509 | 395 | 622 | 63 |
| Mola | 34 | 27,954 | 16,525 | 39,386 | 4,885 |
| Fertilizers and feed (g/$m^2$/season) | | | | | |
| Urea (g N/$m^2$) | 34 | 23 | 7 | 67 | 13 |
| TSP or SSP (g P/$m^2$) | 28 | 15 | 1 | 35 | 8 |
| Cow dung (g C/$m^2$)[b] | 32 | 16 | 1 | 30 | 8 |
| Rice bran (g C/$m^2$)[b] | 34 | 112 | 66 | 192 | 30 |
| Green feed (g dry weight/$m^2$/season) | | | | | |
| Duckweed | 29 | 40 | 0 | 130 | 38 |
| Grass | 33 | 116 | 1 | 345 | 102 |
| Banana leaf | 15 | 112 | 22 | 471 | 113 |
| Total green feed | 34 | 166 | 17 | 569 | 133 |

SIS, small indigenous fish species; TSP, triple superphosphate; SSP, single superphosphate; t/ha, tons/hectare

*a.* The weights of the stocked fish were subtracted from the total fish production.

*b.* Assuming 6.6% carbon in cow dung (wet weight) and 30% carbon in rice bran (wet weight).

Source: Adapted from Roos [27].

(*Barbodes gonionotus*) and common carp (*Cyrinus carpio*) were well suited for rice field culture.

### Perceptions of fish species

**Figure 1** shows the 11 species that received the highest ratings in a study among rural women (*n* = 119) in 1991/92 of their perceptions of the benefits of eating fish species for health and well-being. Many women considered mola and dhela to be full of vitamins and to be good for or to protect the eyes [47].

In the above-mentioned fish-consumption survey in Kishoreganj District, each household member (*n* = 481; mothers reported for their children) was asked to name her or his most preferred fish species for consumption, based on taste. Rui was the single most preferred species, mentioned by 24% of the respondents. Some small indigenous fish species, including mola, were preferred by 30%, whereas puti and silver carp, the species with the highest intakes, were preferred by less than 10% of the respondents.

In a later study of 36 women and men conducted in three villages in Mymensingh District, using focus group discussions and individual interviews, it was reported that even though women were aware that some small indigenous fish species were good for or protected the eyes, the major constraints on promoting vitamin A–rich small indigenous fish species to increase vitamin A intake in pregnant and lactating women were the low availability and accessibility of these species and the lack of awareness and knowledge among men and mothers-in-law of the nutritional needs of pregnant and lactating women [48].

### Teaching, training, and dissemination

The study of small indigenous fish species has been incorporated into the programs of the Faculty of Fisheries, BAU, from which about 100 students graduate annually with B.Sc. or M.Sc. degrees. Research on small indigenous fish species has been the basis for 3 Ph.D. and 16 M.Sc. theses from BAU, as well as 2 Ph.D. and 8 M.Sc. and B.Sc. theses from KVL. In 2002, a workshop entitled "Small indigenous species of fish in Bangladesh: culture potentials for improved nutrition and livelihoods" was hosted by BAU, in which the experience, research, and findings from various areas related to the production, biology, and food and nutritional value of small indigenous fish species were presented and discussed by both national and international participants [49]. The proceedings were published and widely distributed, and afterwards a greater interest in small indigenous fish species was noted at all levels within the fisheries sector. A poster and manual promoting carp–mola polyculture in ponds and other bodies of water, as well as conservation of mola and the nutritional benefits of mola, were developed, tested, published, and widely distributed (**fig. 2**).

One of the highlights of our efforts has been that in mid-2004, the Chief Scientific Officer, Department of Fisheries, issued a directive to all Fisheries Project Directors to implement the carp–mola polyculture production strategy. Dr. Md. Abdul Wahab was requested to draw up a plan of action for the dissemination. The Department of Fisheries has focused on the dissemination of carp–mola polyculture through its Northwest Fisheries Extension Project, covering an area

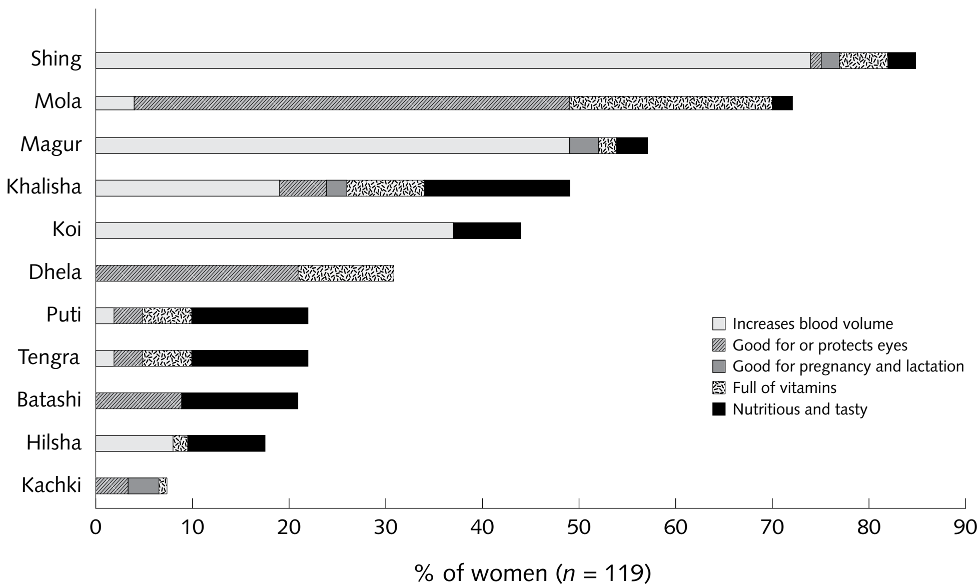


FIG. 1. Perceptions of the benefits of eating fish species for health and well-being among Bangledeshi rural women. The 11 species with the highest ratings are shown. Source: Thilsted and Roos [47].

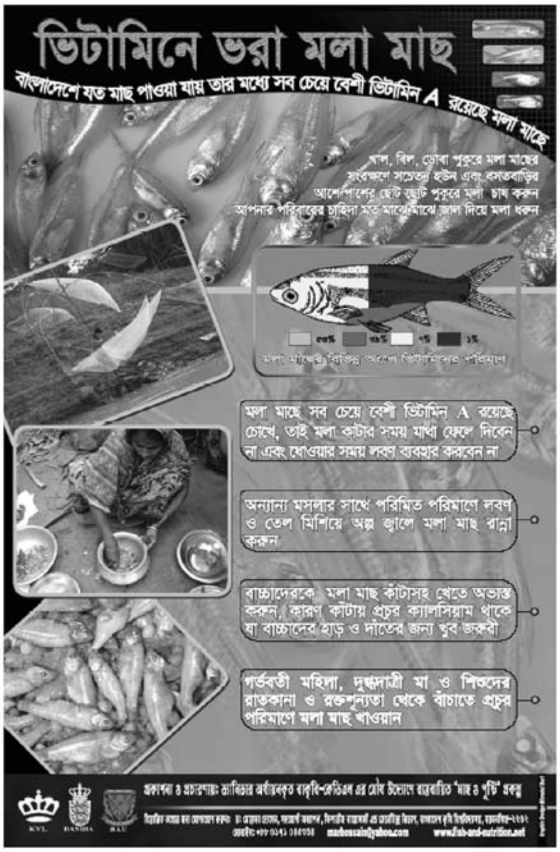


FIG. 2. Poster for the promotion of carp–mola polyculture in ponds and other water bodies, mola conservation, and the nutritional benefits of mola

considered to suffer from food and nutrition insecurity. In addition, the Department of Fisheries has produced a manual for farmers on carp–mola polyculture that has been distributed to all major NGOs and governmental extension agencies in Northwest Bangladesh and Mymensingh District. Researchers from the BAU involved in our activities have assisted the Department of Fisheries in its efforts, including the implementation of pilot-scale projects and farm trials as well as participation in training of extension officers and workshops. Moreover, this production strategy is being disseminated and implemented by NGOs working with poor rural households in other areas of Bangladesh and recently also in Basanti, West Bengal, India.

## Discussion

Our activities and results show that we have been successful in linking human nutrition to fisheries in Bangladesh to address public health problems by documenting and disseminating data on the importance of small indigenous fish species as a commonly consumed, nutrient-dense food in the everyday diet of the poor rural Bangladeshi population. We have used our data to convince many decision makers at many different levels that small indigenous fish species can play an important role in combating micronutrient deficiencies in Bangladesh. In poor rural households in Kishoreganj, we found that small indigenous fish species contributed 40% and 31% of the total recommended intakes of vitamin A and calcium, respectively, at the household level in the peak production season [35]. A committed team of researchers and practitioners was able to use this information to develop and implement carp–mola pond polyculture. Other organizations have been quick to follow; for example, Helen Keller International has expanded its focus on home gardens to include pond polyculture of carp and small indigenous fish species. We have documented that the inclusion of mola in carp polyculture improves the nutritional quality of the fish production without having a negative impact on total fish production. This production system offers a great potential for providing essential limiting micronutrients for the rural poor. If only 10 kg of mola per year were produced in each of the estimated 1.3 million ponds in Bangladesh, the annual recommended vitamin A intake of more than 2 million children could be met [29].

There has been a succession of activities, results, and circumstances that led to this success. It is commonly agreed that mola is a popular and well-liked fish species, and interest in its health and nutritional benefits was awakened when we documented that the perception that mola is good for or protects the eyes was corroborated by its high contents of vitamin A compounds by HPLC analysis [35]. Interest grew even more when it was documented that the high calcium content in mola was as bioavailable as that in milk, commonly regarded as the best source of calcium.

Moving toward developing carp–mola pond polyculture was not difficult, since we proved that mola was particularly suitable for pond polyculture and the inclusion of mola—and other small indigenous fish species—did not lead to a reduction in carp production and thereby in income from sales. Moreover, small farmers and extension officers were ready to give up the use of rotenone, which accounted for about 10% of the total production costs. At the same time, it was recognized that small indigenous fish species could not be prevented from being part of the pond polyculture, since the pond is not a closed system and small indigenous fish species also enter the pond with duckweed. Documenting that mola reproduces in ponds during the production season led to our recommendation that partial harvesting of small amounts could be done biweekly or weekly, favoring household consumption. In contrast, it became more evident that harvesting of carp, which were often harvested all at once and sold immediately to a wholesaler, did not favor household consumption. This inclusion of small indigenous fish species in carp polyculture became even more controversial as we showed that silver carp, the most dominant fish in aquaculture, was not preferred for consumption.

It was important to document that the eyes of mola contained the highest proportion of vitamin A compounds, sun-drying destroyed the vitamin A, and the low plate waste of bones in small indigenous fish species compared with large fish meant that small indigenous fish species have a high content of calcium, whereas the content in large fish is low. This vital information about the contribution of small indigenous fish species to intake of nutrients is disseminated by the manual and poster. Further studies on the effect of processing and cooking on nutrient contents as well as nutrient bioavailability will provide better quantification of the nutritional value of the fish. Because the graduates of the Faculty of Fisheries form the backbone of the fisheries extension service and become officers at the Department of Fisheries, this information may have led to some noticeable changes in the fisheries sector; for example, small indigenous fish species are no longer referred to as "trash" or "weed" fish, either orally or in writing, more attention is paid to monitoring and documenting the changes in capture fisheries, and at the BFRI, more research on small indigenous fish species is being conducted.

As a result of our research as well as other research [3, 40], we recognize that the accessibility of small indigenous fish species continues to decline with the decrease in capture fisheries and the increase in market prices. We have also pointed out that silver carp, because of its low price and even though it is not preferred for consumption, is becoming the most commonly consumed fish species among the rural poor. A study on changes in fish production and accessibility in Kapasia, Gazipur District, from 1990 to 1999 showed that fish from aquaculture contributed an increased share of the fish available in the markets and that in the same period, the accessibility of open-water fisheries to the poorest households declined. The total fish intake as well as the intake of small indigenous fish species decreased, and the increased intake of cultured fish, in particular of silver carp, did not compensate for the loss of micronutrients from the decreased intake of small indigenous fish species [3, 40].

We keep pointing out that the intake of small indigenous fish species goes beyond the delivery of essential, limiting nutrients and that these fish must be viewed as an irreplaceable source of animal food and an integral part of the everyday diet of the rural population, being consumed at high frequency in small amounts. We have therefore been encouraged by the fact that some work has been done on the reestablishment of fish migration routes with connection to floodplains [50]. This has resulted in the restoration of the fish habitat, a fivefold increase in total fish production, and a doubling of the proportion of fish caught (mainly small indigenous fish species) that was consumed by the landless and small farmers after restoration. Much more work must be done with respect to fisheries management and utilization of common fisheries resources in order to ensure that small indigenous fish species continue to play a vital role in the livelihoods, health, and nutrition of rural populations [51].

## Conclusions

The paper describes the successful linking of human nutrition and fisheries in Bangladesh, with the overall objective of combating micronutrient deficiencies. An integrated approach of research and capacity-building activities within the fields of human nutrition and fisheries and specific objectives spanning many different aspects have led to this success. This approach has won approval in other countries, and in Cambodia, together with the Inland Fisheries Research and Development Institute, the research teams from Bangladesh and Denmark are already carrying out similar activities, not in aquaculture but in inland fisheries management. Together with the WorldFish Center, we are seeking financial support to conduct activities in the areas around Lake Victoria and other major inland bodies of water in Africa.

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