4 Valuing aquatic biodiversity in agricultural landscapes

Matthias Halwart

Introduction

This chapter deals with the role of aquatic organisms in agricultural landscapes and in particular their importance for food and nutrition security of rural livelihoods. In this context, aquatic organisms are usually derived from inland capture fisheries from wetlands, streams, rivers, or irrigation canals, and from aquaculture which means the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants mostly in ponds, cages, tanks or rice fields.

Undernutrition is caused by an insufficient intake of food or of certain nutrients or by an inability of the body to absorb and use nutrients. Documented nutrient deficiencies in rural communities include vitamin A, several B vitamins, calcium, iron, zinc, iodine, sulphur-containing amino acids and lysine, and fatty acids of the n-3 series (Halwart et al., 2006). Undernutrition remains a huge and persistent problem, especially in many developing countries, with the bulk of undernourished people living in rural areas. The number of undernourished people in developing countries declined significantly in the 1970s, 1980s and early 1990s, in spite of rapid population growth (FAO, 2011a). However, the incidence of hunger and undernourishment in the world has been dramatically affected by two successive crises – the food crisis first, with basic food prices beyond the reach of millions of poor, and then the economic recession. These crises have had very severe consequences for millions of people, pushing them into hunger and undernourishment. FAO's current estimate of the number of undernourished people in the world in 2009 is 1.02 billion people, which represents more hungry people than at any time since 1970 (FAO, 2011a).

The food and agricultural system as a whole has a key role to play in reducing malnutrition in the world, and the availability of and access to fish is critically important for nutrition and diverse diets especially for the rural poor. Producers can be encouraged to grow a wider variety of crops, including fish, often reviving traditional species and varieties or breeds with high nutritive values. Fish is usually cited as an important source of nutrients and for wild and farmed fish alike often valued for its long-chained omega-3 fatty acids (e.g. Jensen et al., 2012) and fish should be, and in many parts of the world already is, part of a healthy diet. In some places, plants and animals including fish from the forest and the wild contribute variety and taste to otherwise poor rural diets (Ainsworth et al., 2008; Halwart and Bartley, 2005; Jarvis et al., 2007; MAF/FAO, 2007). For those who consume out of their own production or from home or school gardens, diversity in the kinds of foods they grow, gather, fish, or raise is important (Tutwiler, 2012).

It will be argued in this chapter that a focus on the often cited nutritional value of proteins derived from fish (e.g. EC, 2000; ICTSD, 2006) for human nutrition *in agricultural landscapes* certainly is justified to some extent; however, even more important is the role of fish for avoiding micronutrient-related nutritional disorders in developing countries. Examples include anaemia caused by insufficient intake of iron (De Benoist et al., 2008), and impaired sight which is a severe problem because of inadequate intake of vitamin A (WHO, 2009). Such nutrition disorders can be particularly serious in children, since they interfere with growth and development, and may predispose to many health problems, such as infection and chronic disease. Safe and nutritious aquatic foods, selected by nutrition-conscious consumers and caregivers, are therefore critically important in the battle against undernutrition.

Fish availability in inland waters

Fish and other aquatic organisms make an important contribution to food security for many people in agricultural landscapes where they are collected or farmed providing valuable sources of highly nutritious food to all household members. Generally, inland capture fisheries from a wide range of aquatic environments such as swamps, rivers, flood plains and lakes, but also modified habitats such as rice fields or reservoirs produce a large variety of aquatic organisms usually directly consumed and, to a much lesser extent, bartered or sold (Figure 4.1). A recent review on trends of catches is provided by Welcomme (2011a). Aquatic products coming from aquaculture, often farmed in ponds or cages, can also contribute significantly to household nutrition (Swaminathan, 2012). In farming systems where fish are principally intended to be sold they can also provide important benefits indirectly by increasing the purchasing power of farming households for food or for investment in education, access to health services or improvements in household hygiene, all having positive indirect effects on nutrition. There are significant differences in the nutritional value of aquatic food items depending on available species and sizes or developmental form of the organisms. The integration of fisheries, aquaculture and agriculture, innovatively practised by many farmers around the globe, provides numerous options for the sustainable exploitation of a rich diversity of food items that can cover to a large extent the nutritional needs of the different members of the household and the society at large.

The aquatic biodiversity of inland waters useful to humans includes plants, fish, amphibians, reptiles, molluscs, crustaceans and insects. FAO Fisheries and

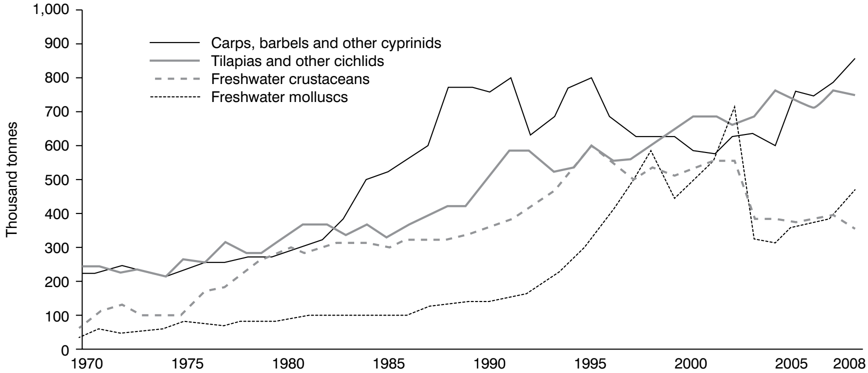


Figure 4.1 Catch trends by major inland waters species group

Aquaculture Department information contributed by member countries in 2010 officially indicates that 10.2 million tonnes were harvested from inland capture fisheries and 36.9 million tonnes from inland aquaculture (FAO, 2012a). However, accurate information on small-scale inland capture fisheries and rural aquaculture is extremely difficult to obtain because of the informal and diffuse nature of these subsectors. Additionally, much of what is caught or produced by small-scale fishers/farmers is consumed by them or bartered locally, and therefore does not enter the formal economy and accounting of national governments. In-depth work has revealed that real production from inland waters is several times higher than that officially reported. It is clear that inland aquatic biodiversity is an important resource for rural communities and often provides a 'safety net' to rely on in the face of other crop and food shortages.

Inland fisheries

In most rural areas of many developing countries, especially landlocked ones, inland fisheries from lakes, floodplains, streams, rivers, and other wetlands including rice fields are very important for food security and income generation. In 1950, inland fisheries produced about 2 million tonnes in terms of fish landings. The figure was about 5 million tonnes in 1980, and, after steady growth of 2–3 per cent per year, 10 million tonnes in 2008. This growth occurred mainly in Asia and Africa, with Latin America making a small contribution. Asia and Africa regularly account for about 90 per cent of reported landings. The remaining 10 per cent is split between North and South America and Europe. The bulk (about 90 per cent) of inland fish is caught in developing countries and 65 per cent is caught in low-income food-deficit countries (LIFDCs). However, much uncertainty surrounds both the trend in and the level of production.

The amount of food produced in inland waters in general (FAO/MRC, 2003) and rice fields (other than rice itself) in particular (Halwart, 2003) is generally

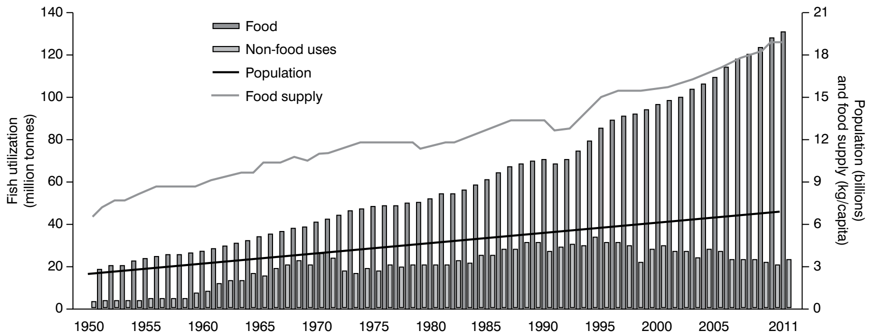


Figure 4.2 World fish utilization and supply. FAO/Aidong Luo

underestimated and undervalued, because it is small quantities (although collected by many individuals and in large areas) which are all locally consumed or marketed, and therefore not recorded in official statistics.

Using a model calculation, Welcomme (2011b) estimated that more than 93 million tonnes could be produced just from the world's lakes. Rice fields have been found to be another important source of origin for fish production. Indeed, the cultivation of rice in irrigated, rain-fed and deepwater systems often offers a suitable environment for fish and other aquatic organisms. Over 90 per cent of the world's rice, equivalent to approximately 134 million hectares, is grown under flooded conditions. It is quite clear that the actual global aquatic food production from inland waters could be much higher than what is currently reported.

Utilization

In developing countries, most of the catch from inland fisheries is processed in small-scale or medium-scale units and goes for domestic consumption (FAO, 2011b) (Figure 4.2). Many rural farmer and fisher families cannot obtain a sufficient variety of nutritious food in their local markets or are simply too poor to purchase it. Cultivated species may be complemented by harvested wild species that can be of particular significance for indigenous communities and for poor and vulnerable communities especially in times of shortage of main staples. Wild and gathered foods, including from the aquatic habitat, therefore provide important diversity, nutrition and food security (Halwart and Bartley, 2007). Trade in inland fish and products are constrained by lack of infrastructure and facilities needed to establish and operate cold chains. This often results in high post-harvest losses, especially quality losses that can amount to up to 40 per cent of the landings. Owing to the remoteness and isolated nature of many inland fishing communities and the high abundance of fish on a seasonal basis, large amounts of fish from inland capture are cured. In Africa, fish processing methods vary according to region and even subregion. Drying and smoking, and to a very small extent fermenting, are the main methods. Some processed freshwater products are considered a delicacy in some countries and are higher priced than similar products prepared using marine fish, e.g. in Ghana, where fresh and salted dried tilapia as well as smoked catfish or perch (*Lates*) are highly preferred. In Asia, a significant proportion of inland fish goes into fish sauce and fish paste. In Cambodia for example, the bulk of the fish caught from the Mekong River in the dai fishery is used for making fish paste (prahoc) and fish sauce (FAO, 2010).

Aquaculture

The farming of inland aquatic species has a much shorter history than farming of crops or livestock and issues, trends and prospects including its role for human nutrition have been comprehensively addressed in a recent Global Conference (FAO/NACA, 2012). Except for the common carp that was domesticated approximately 2,000 years ago, breeding of aquatic species for food is relatively recent. However, the sector is increasing rapidly and represents the fastest growing food producing sector: in 1985 only 73 freshwater species were farmed, in 2000 there were over 150. Today, aquaculture involves the farming of over 540 species of finfish, molluscs, crustaceans and other invertebrates (FAO, 2012a). Traditional animal breeding, chromosome-set manipulation and hybridization have used the genetic diversity of aquatic species such as tilapia, catfish, rainbow trout and common carp to create characteristic breeds of fish to suit environmental and consumer demands (Greer and Harvey, 2004; FAO, 2012b).

World production of food fish

Aquaculture is a growing, vibrant and important production sector. The reported global production of food fish from aquaculture, including finfish, crustaceans, molluscs and other aquatic animals for human consumption, reached 59.9 million tonnes in 2010 out of which 36.9 million tonnes came from inland waters (Table 4.1). In the period 1970–2010, the production of food fish from aquaculture increased at an average annual growth rate of 8.2 per cent, while the world population grew at an average of 1.6 per cent per year. The combined result of development in aquaculture worldwide and the expansion in global population is that the average annual per capita supply of food fish from aquaculture for human consumption has increased by 10 times, from 0.7 kg in 1970 to 7.8 kg in 2008, at an average rate of 6.6 per cent per year (FAO, 2012a).

Globally, aquaculture accounted for 46 per cent of the world's fish food production for human consumption in 2009, up from 42.7 per cent in 2006. Despite the long tradition of aquaculture practices in a few countries over many centuries, aquaculture in the global context is a young food production sector that has grown rapidly in the last five decades. World aquaculture output has increased substantially from less than 1 million tonnes of annual production

Table 4.1 Volume of world aquaculture production of food fish* by major groups of aquatic animals (units: million tonnes). Source: FAO 2012a

Major species group	*1980*	*1985*	*1990*	*1995*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
Freshwater fishes	2.09	4.34	7.14	12.93	17.59	18.59	19.79	20.32	22.20	23.67	25.29	26.62	29.03	30.65	33.74
Molluscs	1.84	2.49	3.61	8.23	9.76	10.29	10.87	11.35	11.84	12.11	12.67	13.03	13.01	13.51	14.16
Crustaceans	0.09	0.26	0.75	1.08	1.69	1.98	2.22	3.00	3.39	3.78	4.26	4.80	5.02	5.34	5.73
Diadromous fishes	0.49	0.67	1.21	1.52	2.25	2.52	2.57	2.68	2.83	2.87	3.00	3.24	3.32	3.53	3.60
Marine fishes	0.19	0.23	0.32	0.55	0.98	1.05	1.16	1.23	1.28	1.44	1.64	1.74	1.95	1.95	1.83
Miscellaneous aquatic animals	0.01	0.03	0.05	0.08	0.16	0.18	0.19	0.33	0.38	0.43	0.42	0.51	0.62	0.73	0.81
World total	4.71	8.02	13.07	24.38	32.42	34.61	36.79	38.92	41.91	44.30	47.29	49.94	52.95	55.71	59.87

* Farmed food fish = farmed finfish, crustaceans, molluscs, amphibians, reptiles (excluding crocodiles) and other aquatic animals (such as sea cucumber, sea urchin, etc.) for human consumption.

in 1950 to 59.9 million tonnes in 2010 (FAO, 2012a), demonstrating three times the growth rate of world meat production (2.7 per cent, from poultry and livestock together) in the same period.

The value of the harvest of world aquaculture, excluding aquatic plants, was estimated at US$119.4 billion in 2010. However, the actual total output value from the entire aquaculture sector should be significantly higher than this figure because the values of aquaculture hatchery and nursery production and the breeding of ornamental fishes have yet to be estimated and included. If aquatic plants are included, world aquaculture production in 2010 was 78.9 million tonnes, with an estimated value of US$125.1 billion (FAO, 2012a).

The above figures demonstrate impressively the increasing importance of aquaculture worldwide and the important role that the farming of fish will increasingly assume both for food security and poverty alleviation.

World production of aquatic plants

Aquaculture produced 19 million tonnes (live weight equivalent) of aquatic plants, mostly seaweeds, in 2010, with a total estimated value of US$5.7 billion. Of the world total production of aquatic plants in the same year, 95.5 per cent came from aquaculture. The culture of aquatic plants has consistently expanded its production since 1970, with an average annual growth rate of 7.7 per cent. The production is overwhelmingly dominated by seaweeds (over 99 per cent by quantity or value in 2010) (FAO, 2012a).

Not included in the above production figures, yet critically important in terms of production in agricultural landscapes and nutrition for national food security particularly in many Asian countries, are freshwater macrophytes such as water spinach, water Neptune, lotus, water caltrops, wild rice (*Zizania aquatica*), water chestnut, prickly water lily and arrow head (*Sagittaria sagittifolia*).

Fish in the diet

Fish diversity

Out of 32,200 fish species described in *FishBase* (Froese and Pauly, 2012), food, industrial (fishmeal and fish oil), ornamental, sport and bait fisheries target about one-sixth, equivalent to 5,000 species. Aquaculture farms over 540 species of finfish, molluscs, crustaceans and other invertebrates, about 50 species of microalgae and invertebrates as food organisms in hatcheries, about 35 species of seaweeds, and over 10 species of amphibians and aquatic reptiles.

Halwart and Bartley (2005) documented the rich variety of aquatic species found and utilized from rice-based systems in Southeast Asia (Box 4.1). A total of 64 aquatic animal species from farmer-managed systems were recorded as being consumed in northeast Thailand, compared with 34 and 19 species in southeast Cambodia and Red River Delta in Viet Nam, respectively (Morales et al., 2006).

Box 4.1 Aquatic species in Southeast Asia

For many rural populations in lowland Southeast Asia, rice and fish are the mainstay of their diet. Aquatic animals represent a significant, often the most important, source of animal protein and are also essential during times of rice shortages (Meusch et al., 2003). Wild and gathered foods from the aquatic habitat provide important diversity, nutrition and food security as food resources from ricefield environments supply essential nutrients that are not adequately found in the diet (Halwart, 2008).

Studies on the availability and use of aquatic biodiversity from rice-based ecosystems in Cambodia, China, Laos and Vietnam documented 145 species of fish, 11 species of crustaceans, 15 species of molluscs, 13 species of reptiles, 11 species of amphibians, 11 species of insects and 37 species of plants directly caught or collected from the rice fields and utilized by rural people during one season (Halwart and Bartley, 2005). Fish usually constitute the major part. Fish plays a major role in supplying food and some income among the groups encountered. Most of it is consumed fresh, but there are a number of ways to preserve it for periods when the supply of fresh fish is interrupted. Among these, drying and fermenting are the most common methods, but fish is also preserved in salt, or smoked; and some aquatic organisms are preserved in alcohol to be used as medicine (Halwart and Bartley, 2005).

Figure 4.3 Snails are being collected regularly from flooded rice fields in P.R. China (Photo: FAO/Aidong Luo)

Fish consumption and composition

In 2009, fish accounted for 16.6 per cent of the global population's intake of animal protein and 6.4 per cent of all protein consumed. Globally, fish provides about 2.9 billion people with almost 20 per cent of their average per capita intake of animal protein, and 4.2 billion people with 15 per cent of such proteins. Annual per capita fish consumption grew from an average of 9.9 kg in the 1960s to 12.6 kg in the 1980s, and reached 17.8 kg in 2007. Of the 17.8 kg of fish per capita available for consumption about 75 per cent came from finfish. Shellfish supplied 25 per cent (or about 4.1 kg per capita), subdivided into 1.6 kg of crustaceans, 0.6 kg of cephalopods and 1.9 kg of other molluscs. Freshwater and diadromous species accounted for about 36.4 million tonnes of the total supply, whereas marine finfish species provided about 48.1 million tonnes (FAO, 2010).

In agricultural landscapes, fish consumption may vary between poorer and richer households. Studies conducted in several Asian countries found that low-income households depend largely on fish as their major animal protein source but generally consume less fish than high-income households (Dey et al., 2005). Another study found that fish in poorer households are often consumed in the 'low-income vegetable-scarce months', when other sources of micronutrients such as vegetables are not available or affordable (Islam, 2007). Significantly higher consumption of fish was found in Nigeria in households engaged in capture fisheries (Gomna and Rana, 2007). Seasonality is another important factor influencing fish harvests, processing and consumption, with cured products being critically important in the diets of rural households during times of low wild fish availability.

Inland aquaculture and integrated agriculture and aquaculture systems usually lead to an increase in household consumption of fish (Prein and Ahmed, 2000). However, as pointed out by Kawarazuka and Béné (2010), this relationship is not straightforward since farmed aquatic products are often viewed as a cash crop rather than a food crop, and the income generated from aquaculture is rarely used to buy smaller lower value fish from the market. Alim et al. (2004) stated that farmers should be given an option so that they could continue to sell their precious cash crop and feed their family with other fish of low market value. A technology of simultaneous culture of popular large carps (as a cash crop) and cheap but nutritious small fish (to feed the family) may satisfy both these needs (Thilsted, 2012). For capture fisheries, case studies from Laos and Papua New Guinea reveal big differences as to whether the majority of the fish caught are being kept for home consumption or not.

Reliable information from published sources on nutritional composition of consumed aquatic organisms is scarce. The importance of fish as a source of animal protein and essential fatty acids is well documented and often cited. A recent expert consultation on the risks and benefits of fish consumption highlighted the importance of fish consumption in order to secure an optimal development of the brain and neural system of children (FAO/WHO, 2011). Several more recent studies stress the role of fish as a source of micronutrients.

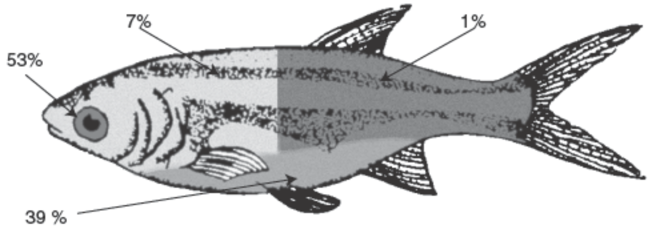


Figure 4.4 Distribution of vitamin A in *Amblypharyngodon mola* (with kind permission after Thorseng 2006, original data from Roos et al., 2002)

Small sized fish are of particular importance since they are consumed whole including bones, heads and organs where concentration of micronutrients is highest (Figure 4.4). Table 4.2 summarizes the data (modified after James, 2006).

DFID (2001) provided indications on the importance of proteins from aquatic organisms in the diet in Southeast Asia. In Northeast Thailand, 72–82 per cent of animal protein consumed in the wet season in Yasothon province comprises wild aquatic resources, derived from rice fields. In Cambodia, fish and fish products account for 70–75 per cent of the dietary protein intake of the population. In Lao PDR, fish had traditionally contributed 85 per cent of animal protein intake. A survey in Luang Prabang province found fish to represent 50–55 per cent of animal protein intake. Fish still represents the largest component of animal protein in the diet. In Viet Nam, fish in An Giang Province contributes nearly 76 per cent of the average person's supply of animal protein, although the role of aquatic resources in the diet of Northern Provinces is considerably less.

Aquatic organisms supply essential and limiting micronutrients that are not found in rice (or found in limited quantities), particularly calcium, iron, zinc and vitamin A. The nutrient content in different fish species may vary by several orders of magnitude (Tetens et al., 1998). As mentioned before, the small fish are of particular importance since they are usually eaten whole. Kawarazuka and Béné (2011) collected evidence from case studies which confirmed the high levels of vitamin A, iron and zinc in some of the small fish species in developing countries. These small fish are reported to be more affordable and accessible than the larger fish and other usual animal-source foods and vegetables. Evidence suggests that these locally available small fish have considerable potential as cost-effective food-based strategies to enhance micronutrient intakes or as a complementary food for undernourished children (Table 4.3).

Hansen et al. (1998) showed that small (4–10 cm) fish eaten with the bones as part of the everyday diet in many Asian countries contribute considerable amounts of calcium. The recommended daily calcium intake for adults can be met by eating 34–43 g of these fresh small fish daily, collecting them from rice fields, ponds and ditches. In Bangladesh, Roos et al. (2007) found that the consumption of small fish contributed 31 per cent of total calcium intake. Similar considerations apply for vitamin A, as this is found particularly in eyes

Table 4.2 Summary of compositional data, per 100 g fresh weight basis

	Protein (g)		*Fat (g)*		*Ca (mg)*		*Fe (mg)*		*Vitamin A (μg)*	
	Min	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Fish	9.7	22.7	0.8	8.0	17	1751	0.6	9.2	5	1800
Crustaceans	10.7	21.2	0.9	3.3	75	5000	0.6	7.5	0	133
Molluscs	7.0	20.2	0.3	1.4	16	2500	7.0	26.6	0	243
Frogs	15.1	20.2	0.2	2.0	19	1293	0.7	3.8	Low	
Insects	3.5	26.2	1.4	8.3	6	120	1.8	30.0	N/D	
Recommended intake, adults, per day*	0.79 g/kg body wt or 10–15% of energy		Min 15% of energy		600–1000 mg		5–24 mg		450–600 μg	

*Modified after James, 2006

Table 4.3 Content of vitamin A and calcium in small and big Bangladeshi fish species (per 100 g raw edible part).

Fish species	*Vitamin A μg*	*Calcium mg*
Small indigenous fish		
Mola (*Amblypharyngodon mola*)	1960	1071
Dhela (*Rohtee cotio*)	937	1260
Chanda (*Chanda* sp.)	341	1162
Puti (*Puntius* spp.)	37	1059
Big fish		
Hilsa (*Hilsa ilisha)*	69	126
Rui (*Labeo rohita*)	27	317
Silver carp (*Hypophthalmichthys molitrix*)	17	268

Source: Tetens et al., 1998

and viscera of small fish (Roos et al., 2002). In Bangladesh, it is commonly believed that the small fish mola (*Amblypharyngodon mola*) is 'good for your eyes', a perception that may have originated from indigenous knowledge that night blindness can be cured by eating mola. Roos et al. (2003) found that the consumption of small fish contributed up to 40 per cent of total vitamin A intake.

Iron deficiency is a widespread nutritional disorder in developing countries. In Cambodia, 16 fish species were screened for iron contents. One local small fish species, *Esomus longimanus,* which is found in ponds, canals and ditches has a higher iron content (451 mg Fe/kg dry matter, $SD = 155$, $n = 4$) than other species. In a field study, 30 rural women were interviewed about traditional use of this species and their cleaning and cooking practices were observed. The amounts of fish consumed were recorded and meal samples were collected for iron analysis. Calculations based on the iron content and a high bioavailability of Hm-Fe showed that a traditional fish meal (sour soup) covered 45 per cent of the daily iron requirement for women (Roos et al., 2007).

Another group of particular nutritional importance is the essential fatty acids which are critical for maternal, fetal and neonatal nutrition. The health attributes of fish are particularly due to long-chain n-3 polyunsaturated fatty acids. However, it has been noted that fish contain many other important nutrients that also contribute to the health benefits of fish, and the health effects of fish consumption may be greater than the sum of the individual constituents (FAO/WHO, 2011). Eating fish is also part of the cultural traditions of many peoples. In some countries, where viable options for substitute foods are extremely limited, fish is the major source of protein and other essential nutrients. A review of the potential benefits of fish for maternal, fetal and neonatal nutrition is provided by Elvevoll and James (2000).

Many rural farmer and fisher families in developing countries cannot obtain a sufficient variety of nutritious food in their local markets or are simply too poor to purchase it. Cultivated species may be complemented by harvested wild species that can be of particular significance for indigenous communities and for poor and vulnerable communities, especially in times of shortage of main staples. Wild and gathered foods, including from the aquatic habitat, therefore provide important diversity, nutrition and food security (Halwart and Bartley, 2007). Available information on nutrient composition of aquatic species and their consumption is limited, and sometimes inadequate (Halwart, 2006).

Case study: Laos

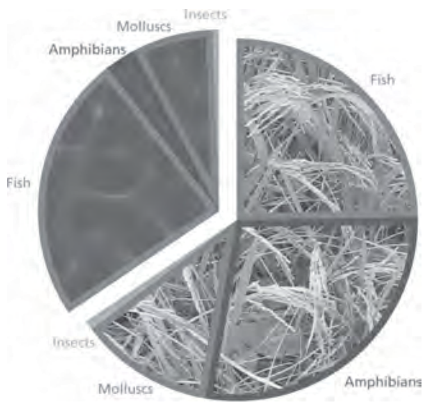
The role of aquatic ricefield species in rural Laotian diets has been underestimated, as almost 200 species are consumed, supplying a range of nutrients needed by the villagers. A recent consumption study in Laos shows that rice fields are the source of about two-thirds of all aquatic organisms consumed by rural households, whilst for fish alone it is about 50 per cent. About one-third of all consumed organisms are frogs and most of these come from rice fields (Box 4.2).

Nevertheless, national and regional food composition databases contain limited information on the nutritional composition of these species. The aquatic animals consumed on a daily basis contained high amounts of protein (11.6–19.7 per cent for fish, crustaceans, molluscs, amphibians and insects and 3.3–7.8 per cent for fermented fish), and a generally acceptable essential amino acid profile. They were also excellent sources of calcium, iron and zinc. However, they had low contents of fat (0.1–4.6 per cent), fatty acids and vitamin A. Essential amino acids, iron and zinc are nutrients that are scarce in rural Laotian diets. As the food supply of rural households in rice farming areas of Laos is critically dependent on the environment, the sustainable existence of the ricefield aquatic animals is a crucial factor for the nutritional status of the Laotians (Nurhasan et al., 2010).

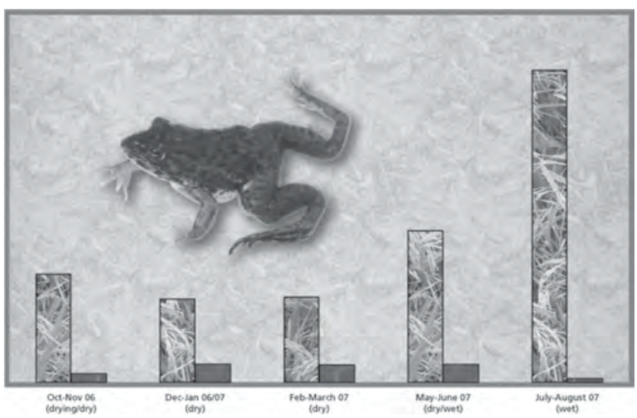
Box 4.2 Aquatic biodiversity and nutrition: the contribution of rice-based ecosystems in the Lao PDR

A monthly household survey has been conducted in 240 households in three provinces of the Lao PDR which were selected to represent the different topographical and agro-ecological zones of the country. The survey yielded information on acquisition, amount and uses of fish and other aquatic animals (OAAs) based on 24-hour recall of the respondents over a one-year period ending October 2007. Data were obtained on catch and habitats, species and biodiversity, household consumption of fish and OAAs, and relationship between catches and village resources/village pesticide use.

The results of this survey show that rice fields contribute far more to people's livelihood and food security than just the rice alone: Two-thirds of all the aquatic animals and 50% of all fish consumed by the surveyed households come from the ricefield habitat:



Generally, habitats outside the ricefield zone play a more important role as food source for rural people in the dry season, while the importance of habitats within the rice-based ecosystem increases significantly in the wet season. Exceptional in this respect are frogs which make up around one-third of all the aquatic animals consumed and are thus second in importance for food supply after the fish. Frogs are caught predominantly in the rice fields, even in the dry season:



The study has impressively demonstrated that ricefield habitats including the rice fields themselves, natural ponds/trap ponds in rice fields and rice field streams/canals are important for aquatic animals which in turn are important as an everyday source of food for the people in rural areas.

Source: FAO/LARReC 2007

Valuing small fish and integrated production systems

Historically, fish were mostly captured and collected from the 'wild', including from agricultural production systems. Due to a combination of factors, and largely driven by a steady human population increase, these common resources have declined. Aquaculture can make up for the deficit but whether this will have the desired nutritional effects for local households will depend among others on the appropriate selection of aquatic species and the broader species composition in various production systems. Nutrient dense small sized fish species can be cultured alongside larger aquatic species to allow for both food-based and cash crop aquaculture and nutrition development strategies. Not enough attention has been paid so far to these small self-recruiting species and their potential in aquaculture development, particularly their potential to combat micronutrient deficiencies of vulnerable parts of the society such as pregnant and lactating women and small children. In addition, more attention should be paid to processing methods for dual reasons of improved fish availability during lean periods and reducing post-harvest losses.

Because of the multiple uses of inland waters, integration of such use becomes important and constitutes other hierarchies of biodiversity at the ecosystem and landscape levels. The requirements of fish and fisheries should be duly taken into consideration in planning and management. Where watersheds have been modified by hydro-electric development, mitigation measures need to be implemented, e.g. habitat rehabilitation, specific water-management programmes and fish-passage systems, to protect species that depend on longitudinal and lateral movements to complete their life cycle successfully.

Although rural people in developing countries may refer to themselves as farmers, the use of inland resources is often an integrated part of their livelihoods. The frequency and the ways in which they use aquatic organisms vary seasonally and with the cultural and geographic setting. Agricultural policies need to ensure that fishing or aquaculture which takes place in rice paddies are valued in economic as well as nutritional terms, taking into due account farmers' motivation to farm without the use of pesticides because the animals serve as natural predators and grazers. Animals in rice paddies can either be natural components of biodiversity that are 'trapped' in the paddies, or they can be purposefully stocked, such as many tilapia, barb and carp species. Especially in small-scale production systems, pond culture of larger fish intended for sale can be complemented by the concurrent culture of smaller nutrient-dense fish intended for household consumption. Agricultural policies should encourage such integrated use.

Agriculture and aquaculture can form integrated farming systems where nutrients are cycled between production components, where fish ponds can provide a source of water for irrigation, and where irrigation systems can be fished. Aquaculture is further used to support culture-based fisheries. There is also a trend for inland water biodiversity to be supplemented or even constructed to maximize benefits from the modified systems.

Clearly, enough attention has not been given to the aquatic diversity naturally found in agricultural ecosystems and its importance to rural livelihoods. Raising awareness and making this aquatic biodiversity in rice 'visible' is important and supported by relevant international codes and guidelines (FAO, 1995, 2005). As the first international forum, the International Rice Commission (IRC) has recognized the above results and recommended that 'Member countries should promote the sustainable development of aquatic biodiversity in rice-based ecosystems, and policy decisions and management measures should enhance the living aquatic resource base' (FAO, 2002). This was followed by a recommendation from the 21st IRC Session in 2006 stating that 'Member countries should, when appropriate, promote at all levels – particularly through national agriculture and rice development programmes and policies – the development and transfer of integrated rice–fish systems to enhance economic competitiveness of rice production, human nutrition, rural income and employment opportunities. Promotion should be based on identification of suitable areas, selection of nutrient-rich local aquatic species and appropriate farming practices. Under marginal rice-production conditions such as low-yield monsoon seasons new agro-enterprise such as aquaculture can lead to improved income and food security. An expert meeting to explore these options and to guide pilot development is recommended.'

Similarly, the Convention on Biological Diversity (CBD) at its 10th Conference of Parties welcomed Resolution X.31 of the tenth meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971) on the subject 'Enhancing biodiversity in rice paddies as wetland systems', noting the culture of rice in 114 countries worldwide, that rice paddies (flooded and irrigated fields in which rice is grown) have provided large areas of open water for centuries and that they support a high level of rice associated biodiversity important for sustaining rice paddy ecosystems, as well as providing many other ecosystem services. The CBD adopted decision X/34 on Agricultural Biodiversity, recognizing the importance of agro-ecosystems for the conservation and sustainable use of biodiversity, and invited the Food and Agriculture Organization of the United Nations to undertake further studies on the valuation of the biodiversity and ecosystem services provided by agricultural ecosystems, in order to further support policy-relevant guidance to Parties for consideration by the Conference of the Parties at its eleventh meeting.

Various alternatives of integration of aquaculture have been examined and reviewed (e.g. Pullin and Shehadeh, 1980; Little and Muir, 1987; FAO et al., 2001; Halwart and Gupta, 2004; Morales et al., 2006) and show that this type of farming efficiently uses land, water and nutrients producing high-quality food. However, this has clearly not been a sufficient enough precondition for their wider acceptance and distribution. More recently, new approaches taking better into account the socio-economic circumstances of farming communities are being tried and supported through FAO and partners' work in countries such as Burkina Faso, Cambodia, Guyana, Lao PDR, Mali, or Suriname, following a Farmer Field School (FFS) approach which is a discovery based learning approach where small groups of farmers meet regularly facilitated by a specially trained technician, to explore new methods, through simple experimentation and group discussion and analysis, over the course of a growing season. This allows farmers to modify and adapt newly introduced methods to local contexts and knowledge, ultimately providing a higher likelihood of appropriate adaptation and adoption of improved technologies. It is only relatively recently that aquaculture has been integrated into an FFS-style curriculum (Halwart and Settle, 2008). The validation and dissemination of integrated fish farming in rice-based systems through Farmer Field Schools is currently being tested in field activities in Mali and Burkina Faso (Yamamoto et al., 2012), where considerable potential for the integration of irrigation and aquaculture exists (Halwart and Van Dam, 2006).

It is now important that countries mainstream successful experiences from farming communities and corresponding recommendations from international fora into their agricultural and nutritional development plans, policies and strategies, as is currently the case in Lao PDR (Vatthanatham et al., 2007). Ultimately, the understanding of the value of aquatic biodiversity from agricultural ecosystems for food and nutrition needs to be well integrated into national agricultural systems that embrace the concepts of an ecosystem approach and the role of agricultural biodiversity for people and the environment.

Acknowledgements

The author would like to thank colleagues and friends in FAO who have contributed to SOFIA and World Aquaculture 2010 which provided basic information for this chapter, and to FAO Aquaculture Statistician Xiaowei Zhou who ensured that accurate and most recent information is being reported. Jogeir Toppe provided valuable comments on an earlier draft. Claudia Aguado-Castillo assisted with the copy-editing of the chapter. This chapter was realized thanks to the encouragement of Danny Hunter of Bioversity which is also gratefully acknowledged.

Note

The views expressed in this publication are those of the author(s) and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations

References

Ainsworth, D., Aitken, S., Catling, P., Dang, P.T., Douglas, H., Fraleigh, B., Hall, P., Parker, D., Pratt, N., Small, E. (eds) (2008) 'The value of biodiversity to food and agriculture', *Biodiversity – Journal of life on earth*, vol 9, numbers 1&2, http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/Pub/Biodiversity.pdf

Alim, M.A., Wahab, M.A. and Milstein, A. (2004) 'Effects of adding different proportions of the small fish punti (*Puntius sophore*) and mola (*Amblypharyngodon mola*) to a polyculture of large carp', *Aquaculture Research,* vol 35, pp.124–133.

De Benoist, B., McLean, E., Egli, I., Cogswell, M. (eds) (2008) 'Worldwide prevalence of anaemia 1993–2005', *WHO Global Database on Anaemia*, WHO, Geneva. p.40.

Dey, M.M., Rab, M.A., Paraguas, F.J., Piumsombun, S., Bhatta, R., Alam, M.F., Ahmed, M. (2005) 'Fish consumption and food security: a disaggregated analysis by types of fish and classes of consumers in selected Asian countries', *Aquaculture Economics and Management,* vol 9 pp.89–111.

DFID (2001) 'Aquatic resources management for sustainable livelihoods of poor people', pp.11–16, in IIRR, IDRC, FAO, NACA and ICLARM, *Utilizing Different Aquatic Resources for Livelihoods in Asia: a resource book.* International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organization of the United Nations, Network of Aquaculture Centers in Asia-Pacific and International Center for Living Aquatic Resources Management.

Elvevoll, E.O. and James, D.G. (2000) 'Potential benefits of fish for maternal, fetal and neonatal nutrition: a review of the literature', *Food, Nutrition and Agriculture*, vol 27, pp.28–39.

European Commission (2000) *Fisheries and Poverty Reduction*, Communication from the Commission to the Council and the European Parliament. Commission of the European Communities, Brussels, p.20, http://ec.europa.eu/development/icenter/repository/COM_2000_0724_en.pdf, accessed July 2012.

FAO (1995) *Code of Conduct for Responsible Fisheries*, Rome, FAO, p.41.

FAO (2002) Report of the 20th Session of the International Rice Commission held in Bangkok, Thailand from 23–26 July 2002, FAO, Rome, p.46.

FAO (2005) 'Voluntary guidelines to support the progressive realization of the right to adequate food in the context of national food security', adopted by the 127th Session of the FAO Council, November 2004.

FAO (2010) *The State of the World Fisheries and Aquaculture 2010,* FAO, Rome, p.197.

FAO (2011a) *The State of Food and Agriculture 2010–2011. Part II – World food and agriculture in review – Trends in undernourishment*, FAO, Rome, p.147.

FAO (2011b) *World aquaculture 2010,* FAO Fisheries and Aquaculture Department, Technical Paper, no 500/1, Rome, p.105.

FAO (2012a) *Aquaculture production statistics dataset (quantity and value) 1950–2010*, FAO, Rome.

FAO (2012b) 'FAO International Expert Workshop Improving the Information Base for Aquatic Genetic Resources for The State of the World's Aquatic Genetic Resources', Madrid, Spain, 1–4 March 2011, Rome, p.57.

FAO, IIRR and ICLARM (2001) 'Integrated agriculture-aquaculture: a primer', *FAO Fisheries Technical Paper*, no 407, Rome, p.149.

FAO/LARReC (2007) 'Aquatic biodiversity in rice-based ecosystems for Lao PDR', Technical Paper, FAO – Netherlands Partnership Programme (FNPP) 2006–2007 (unpublished).

FAO/MRC (2003) 'New approaches for the improvement of inland capture fishery statistics in the Mekong Basin', Report of the Ad Hoc Expert Consultation held in Udon Thani, Thailand, 2–5 September 2002, FAO/RAP Publication 2003/01, FAO/RAP, Bangkok, p.145.

FAO/NACA (2012) *Farming the Waters for People and Food*, R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan and P. Sorgeloos (eds) Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand, 22–25 September 2010, FAO, Rome and NACA, Bangkok, p.896.

FAO/WHO (2011) 'Report of the Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption', *FAO Fisheries and Aquaculture Report* no 978, Rome, Food and Agriculture Organization of the United Nations; Geneva, World Health Organization, p.50.

Froese, R. and Pauly, D. (eds) (2012) *FishBase*, online, www.fishbase.org, accessed July 2012.

Gomna, A. and Rana, K. (2007) 'Inter-household and intra-household patterns of fish and meat consumption in fishing communities in two states in Nigeria', *British Journal of Nutrition*, vol 97, no 1, pp.145–152.

Greer, D. and B. Harvey (2004) *Blue Genes – sharing and conserving the world's aquatic biodiversity*, Earthscan and IDRC.

Halwart, M. (2003) 'Recent initiatives on the availability and use of aquatic organisms in rice-based farming', pp.195–205, in Dat van Tran (eds) *International Rice Commission – Sustainable rice production for food security*. Proceedings of the 20th Session of the International Rice Commission, Bangkok, Thailand, 23–26 July 2002.

Halwart, M. (2006) 'Biodiversity and nutrition in rice-based aquatic ecosystems', *Journal of Food Composition and Analysis,* vol 19, pp.747–751.

Halwart, M. (2008) 'Biodiversity, nutrition and livelihoods in aquatic rice-based systems', *Biodiversity: Journal of Life on Earth,* vol 9, no 1 and 2*, Special Biodiversity & Agriculture*, CBD & IDRC, pp.36–40.

Halwart, M. and Bartley, D. (eds) (2005) *Aquatic biodiversity in rice-based ecosystems. Studies and reports from Cambodia, China, Lao PDR and Viet Nam*. [CD-ROM], Rome, FAO, ftp://ftp.fao.org/FI/CDrom/AqBiodCD20Jul2005/Start.pdf, accessed July 2012.

Halwart, M. and Bartley, D. (2007) 'Aquatic biodiversity in rice-based ecosystems', pp.181–199, in D.I. Jarvis, C. Padoch and H.D. Cooper (eds) *Managing biodiversity in agricultural ecosystems*, Columbia University Press, p.492.

Halwart, M. and Gupta, M.V. (2004) *Culture of fish in rice fields*, FAO and the WorldFish Center, Penang Malaysia.

Halwart, M. and Settle, W. (eds) (2008) 'Participatory training and curriculum development for Farmer Field Schools in Guyana and Suriname', *A field guide on Integrated Pest Management and aquaculture in rice*. Rome, FAO, pp.116, http://www.fao.org/docrep/012/ba0031e/ba0031e.pdf, accessed July 2012.

Halwart, M. and Van Dam, A.A. (2006) 'Development of integrated irrigated and aquaculture in West Africa: the way forward', in M. Halwart and A.A. van Dam, (eds) *Integrated irrigation and aquaculture in West Africa: concepts, practices and potential*, pp.169–174, Rome, FAO, p.181.

Halwart, M., Bartley, D., Burlingame, B., Funge-Smith, S., James, D. (2006) 'FAO Regional Technical Expert Workshop on aquatic biodiversity, its nutritional composition, and human consumption in rice-based systems', *Journal of Food Composition and Analysis,* vol 19, pp.752–755.

Hansen, M., Thilsted, S.H., Sandstrőm, B., Kongsbak, K., Larsen, T., Jensen, M. and Sorensen, S.S. (1998) 'Calcium absorption from small soft boned fish', *J. Trace Elements Med. Biol.,* vol 12: pp.148–154.

ICTSD (2006) *Fisheries, International Trade and Sustainable Development,* International Centre for Trade and Sustainable Development, Geneva, http://www.thew2o.net/events/highseas/docs/Fish_policypaper_exec.pdf, accessed July 2012.

Islam, F.U. (2007) *Self-recruiting species in aquaculture: Their role in rural livelihoods in two areas of Bangladesh*, https://dspace.stir.ac.uk/bitstream/1893/206/1/Islam%20AFU-PhD%20Thesis_2007.pdf, accessed July 2012.

James, D. (2006) 'The impact of aquatic biodiversity on the nutrition of rice farming households in the Mekong Basin: Consumption and composition of aquatic resources', *Journal of Food Composition and Analysis,* vol 19, pp.756–757.

Jarvis, D.I., Padoch, C., Cooper, H.D. (eds) (2007) *Managing biodiversity in agricultural ecosystems*, Columbia University Press, pp.492.

Jensen, I.J., Mæhre, H.K., Tømmerås, S., Eilertsen, K.E., Olsen, R.L. and Elvevoll, E.O. (2012) 'Farmed Atlantic salmon (*Salmo salar L.*) is a good source of long chain omega-3 fatty acids', *Nutrition Bulletin*, vol 37, no 25–29. doi: 10.1111/j.1467-3010.2011.01941.x.

Kawarazuka, N. and Béné, C. (2010). 'Linking small-scale fisheries and aquaculture to household nutritional security: an overview', *Food Security* 2: pp.343–357.

Kawarazuka, N. and Béné, C. (2011) 'The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence', *Public Health Nutrition*, vol 14, no 11, pp.1927–1938.

Little, D. and Muir, J. (1987) 'A guide to integrated warm water aquaculture', *Institute of Aquaculture Publications*, University of Stirling, Scotland, UK.

MAF/FAO (2007) *Aquatic biodiversity and human nutrition – the contribution of rice-based ecosystems*, Ministry of Agriculture and Forestry Laos and FAO, Rome, ftp://ftp.fao.org/docrep/fao/010/ai759e/ai759e04.pdf, accessed July 2012.

Meusch, E., Yhoung-Aree, J., Friend, R. and Funge-Smith, S. (2003) *The role and nutritional value of aquatic resources in the livelihoods of rural people, A participatory assessment in Attapeu Province, Lao PDR*. FAO/LARReC/IUCN, Bangkok, Thailand, ftp://ftp.fao.org/docrep/Fao/004/AD454e/ad454e00.pdf, accessed July 2012.

Morales, E.J., Little, D.C., Immink, A., Demaine, H., Yakupitayage, A., Amilhat, E., Lorenzen, K. (2006) 'Project report: Contribution of self-recruiting species produced in farmer-managed aquatic systems in rural areas of Southeast Asia to food consumption', *Journal of Food Composition and Analysis,* vol 19: pp.759–760.

Nurhasan, M., Maehre, H.K., Malde, M.K., Stormo, S. K., Halwart, M., James, D., Elvevoll, E.O. (2010) 'Nutritional composition of aquatic species in Laotian rice field ecosystems', *Journal of Food Composition and Analysis,* vol 23, pp.205–213.

Prein, M. and Ahmed, M. (2000) 'Integration of aquaculture into smallholder farming systems for improved food security and household nutrition', *Food and Nutrition Bulletin*, vol 21, pp.466–471.

Pullin, R.S.V. and Shehadeh, Z.H. (1980) *Integrated agriculture–aquaculture farming systems*, International Center for Living Aquatic Resources Management (WorldFish Center), Penang, Malaysia.

Roos, N., Leth, T., Jakobsen, J., and Thilsted, S.H. (2002), 'High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency', *Int. J. Food Sci. Nutr.,* vol 53: pp.425–437.

Roos, N., Islam, M.M., Thilsted, S.H. (2003) 'Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium and iron intakes', *Journal of Nutrition*, vol 133, pp.4021–4026.

Roos, N., Thorseng, H., Chamnan, C., Larsen, T., Gondolf, U., Bukhave, K., Thilsted, S.H. (2007) 'Iron content in common Cambodian fish species: Perspectives for dietary iron intake in poor, rural households', *Food Chemistry,* vol 104, pp.1226–1235.

Swaminathan, M.S. (2012) 'Aquaculture and sustainable nutrition security in a warming planet', Keynote Address 1, in R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan and P. Sorgeloos (eds) *Farming the Waters for People and Food*. Proceedings of the Global Conference on Aquaculture

2010, Phuket, Thailand. 22–25 September 2010, pp.3–19, FAO, Rome and NACA, Bangkok.

Tetens, I., Thilsted, S.H., Choudhury, N.H., Hassan, N. (1998) 'The rice-based diet in Bangladesh in the context of food and nutrition security', *Scandinavian Journal of Nutrition,* vol 42, pp.77–80.

Thilsted, S.H. (2012) 'The potential of nutrient-rich small fish species in aquaculture to improve human nutrition and health', in R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan and P. Sorgeloos (eds) *Farming the Waters for People and Food*. Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand, 22–25 September 2010, pp.57–73. FAO, Rome and NACA, Bangkok.

Thorseng, H. (2006) 'Contribution of iron from *Esomus longimanus* to the Cambodian diet: studies on content and in vitro availability', MSc thesis. Frederiksberg, Denmark: Department of Human Nutrition, The Royal Veterinary and Agricultural University 2005 – data presented at the National Conference on Prioritizing Fisheries for Cambodia's National Development and Community Aspiration, organized by IFReDI/DoF, WorldFish Center and CDRI at Sihanoukville, Cambodia. 14–15 February 2006.

Tutwiler, A. (2012) *Global Forum on Food Security and Nutrition. Digest* no 947, 'Linking Agriculture, Food Systems and Nutrition: What's your perspective?' FSN Forum.

Vatthanatham, K., Phothitay, C., Roger, K., Khamsivilay, L., Garaway, C., Bamrungrach, P. and Halwart, M. (2007) 'Importance of aquatic biodiversity in rice-based ecosystems: policy impact in Lao PDR', in *Book of Abstracts, Fisheries and Aquaculture: Strategic outlook for Asia*, 8th Asian Fisheries Forum, 20–23 November 2007, Kochi, India, pp.244–245.

Welcomme, R. (2011a) 'Review of the state of the world fishery resources: Inland fisheries', *FAO Fisheries and Aquaculture Circular,* no 942, Rev. 2, Rome, FAO, pp.97.

Welcomme, R.L. (2011b) 'An overview of global inland fish-catch statistics: International', *Journal of Marine Science,* FDI special issue, no 3529.

WHO (2009) 'Global prevalence of vitamin A deficiency in populations at risk 1995–2005', WHO Global Database on Vitamin A Deficiency, World Health Organization, Geneva, pp.55.

Yamamoto, K., Halwart, M. and Hishamunda, N. (2012), 'FAO supports African rice farmers in their diversification efforts through aquaculture', *FAO Aquaculture Newsletter,* vol 48, pp. 42–3.