At the Nexus of Food and Water: Fish for a Food Secure Future

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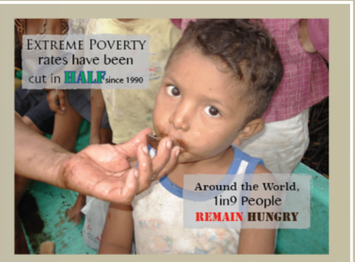
Introduction

To meet the demands of a rapidly growing population (exceeding 7 billion by 2020), a rising middle class, and an increasingly urban population (65% by 2020), meat consumption is expected to increase to 45kg per capita by 2020, a 25% increase from 1997. The fish consumption rate is no outlier, absorbing an increasing amount of this demand for meat, and offering techniques that offset some of the environmental costs of production. Relative to the expense and environmental impacts of producing beef, pork, mutton, and poultry, fish production can offer a more sustainable alternative. Depending on the species and farming method, fish production can achieve some of the lowest feed-conversion ratios of any type of terrestrial animal meat production. For example, the cultivation of lower trophic-level fish species can employ non-fed techniques where fish rely on in-pond productivity for food, with nutrient input decisions and pond management techniques ultimately determining the cost effectiveness.

Research on alternative proteins in feeds and digestibility to increase efficiencies can allow small-scale fish farmers to rely less on feeds derived from higher trophic level animals. Sustainable aquaponics systems and integrated aquaculture are combining fish farming with agriculture by using a carrying capacity approach for products at various trophic levels. As the global community shifts to an urban-dominated population with increases in disposable income, sustainable food choices need to be available. Many fish farming techniques are already helping to meet increasing demands, while continued research and outreach in sustainability and accessibility will make additional choices available to consumers looking for responsibly produced animal protein.

The world is changing-

High rates of malnutrition coupled with an increasing demand for animal-sourced protein by a growing urban population is creating a growing pressure on the global food system.

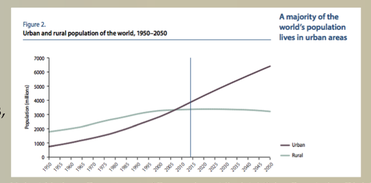


There are fewer poor people, yet there are still high rates of malnutrition and food insecurity. With increasing urbanization, the demand for food is nuanced with the need for highly nutiritous food and animal protein.

- Though 700 million fewer people live in conditions of extreme poverty today than in 1990, nearly 800 million people still suffer from hunger and as many as two billion suffer from malnutrition
- The prevalence of undernourishment is concentrated in developing countries, where 13.5% of the population is undernourished
- 1 in 6 children in developing countries is underweight and about 200 million under 5 years of age are undernourished
- The global population is expected to exceed 7 billion by 2020

Urbanization is rising from 54% today, to a projected 65% by 2020

- With urbanization increasing, **meat consumption is expanding**
- As incomes rise, people tend to eat more meat, dairy products, fruits, vegetables & oils—increasing the demand for raw commodities
- By 2020, it is anticipated that the total meat consumption will increase to 63% from 52% in 2003.
- Meat consumption is increasing at a higher rate (~3% per year) in developing nations than developed countries (~0.8% per year)
- As a good source of protein and essential micronutrients, fish is no outlier in these food demands



United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).

Sustainable aquaculture...

A street vendor selling tilapia on the outskirts of Lake Victoria in Kenya.


Snakehead retailer in a Cambodian marketplace.

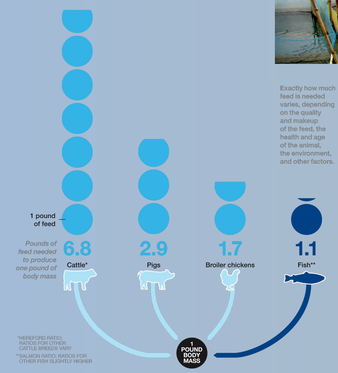
"People have never consumed so much fish or depended so greatly on the fisheries and aquaculture sector for their nutrition as they do today, but the demand for fish is growing and there are still huge numbers of hungry and malnourished people in the world. Aquaculture plays an essential role in meeting these challenges" (FAO, 2014).

Aquaculture is poised to contribute several key ingredients in the global diet, particularly as the demand for protein increases. As the climate changes, the global population rises, and urbanization proliferates, attaining global food security will be increasingly complex. To address this issue, the **AquaFish Innovation Lab**'s overall mission is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquaculture and fisheries in environmentally sensitive and socially acceptable ways.


Fish ponds in Uganda.


Harvesting fish in Bangladesh.

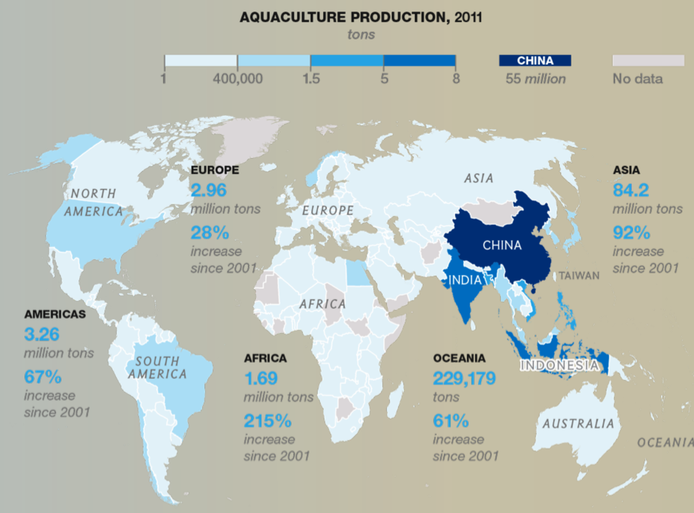
- Depending on the species, aquaculture can achieve **low feed-conversion ratios** (how efficiently the fish converts food to meat).
- Fish **require fewer inputs** than other animal-source proteins to produce a given amount of meat.
- Many lower trophic-level fish species can consume mostly plant-based diets, **reducing the demand for resources** required for healthy fish feed and freeing up those resources to be used for human consumption.
- Aquaculture **has a smaller carbon and water footprint** than other meat sources due to the relatively low inputs for producing fish protein.
- The bioenergetics of fish growth in a 3-D space provide additional efficiencies.



www.nationalgeographic.com/foodfeatures/aquaculture/

Nutritional Comparison of Aquatic and Terrestrial 'Livestock' Products

Nutritional Value (raw, 100g serving)	Tilapia	Carp	Catfish (Channel, farmed)	Oyster (farmed)	Shrimp	Pig (pork loin)	Chicken (broilers, fryers, meat only)	Cow (ground beef)	Goat	Eggs (chicken)	Milk (cow)
Macronutrients											
Calories (kcal)	96	127	119	59	71	120	119	333	109	143	61
Fat (g)	1.7	5.6	5.9	1.6	1.0	3.5	3.1	30	2.31	9.5	3.3
Protein (g)	20.1	17.8	15.2	5.2	13.6	20.6	21.4	14.4	20.6	12.6	3.2
Vitamins											
Vit. A (e.g. mola)(µg)	0	9	0	8	54	0	16	14	0	160	46
Vit. B6 (mg)	1.62	0.19	0.15	0.06	0.16	0.80	0.43	0.30	NA	0.17	0.01
Niacin (mg)	3.91	1.64	2.11	1.23	1.78	6.60	8.20	3.40	3.80	0.07	0.10
Folate (µg)	24	15	10	18	19	0	7	9	5	47	5
Minerals											
Iron (mg)	0.56	1.24	0.23	5.78	0.21	0.97	0.89	1.64	2.83	1.75	0.03
Zinc (mg)	0.33	1.48	0.48	37.92	0.97	1.90	1.54	3.60	4.00	1.30	0.37
Calcium (mg)	10	41	8	44	54	6	12	24	13	56	113
Magnesium (mg)	27	29	19	33	22	27	25	14	NA	12	10
Fatty Acids											
omega-3 Poly-unsat (g)	0.36	1.43	1.12	0.59	0.30	0.57	0.75	0.70	0.17	1.90	0.19
Feed conversion ratio	1.5	1.5	1.4	NA	1.6	3.7	2.9	27	8.6	2.3	1.2



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Sustainable aquaculture production will require alternative protein sources for fish feeds. Fish meal and fish oil are important ingredients for many farmed animals from pigs to fish, supplying essential amino and fatty acids critical for normal growth. However, the environmental and the economic costs of fish meal and fish oil continue to rise as global demand increases, and harvest of wild fish stocks for human consumption drives down availability and places even greater pressure on the world's fisheries. Feed costs and environmental impacts are also rising through the supply chain because of increasing demand and transport costs for feed inputs. Development of alternative proteins in fish feeds is increasingly essential to offset the environmental and economic costs of aquaculture and increase sustainability. Below are examples of how the AquaFish Innovation Lab is contributing to the effort of identifying viable alternative proteins for aquaculture feeds:

- In Tanzania, AquaFish researchers conducted feed trials for tilapia using leaf meals from the locally available native trees *Moringa oleifera* and *Leucaena leucocephala* as protein substitutes. Results show that the *Moringa* diets produced tilapia of similar size and quality, with similar apparent protein digestibility as soy-protein diets. However, *Moringa* is potentially more valuable to Tanzanians as an export product than as fish feed, because of the demand for this plant in the nutraceutical market.
- In some cases, animal-based proteins are considered better alternatives than plant-based proteins for fish diets because of their **superior amino acids, micronutrients, and digestibility.** AquaFish researchers are currently investigating a promising new protein source for fish feed: **invertebrates, such as insects and earthworms**, which have higher protein content and higher digestibility than plant-based proteins.
- Moreover, these invertebrates are abundant, fast-growing, and low trophic-level species, making them a sustainable alternative protein source for fish feed.


Earthworm culture trays for fishfeed study in Tanzania.

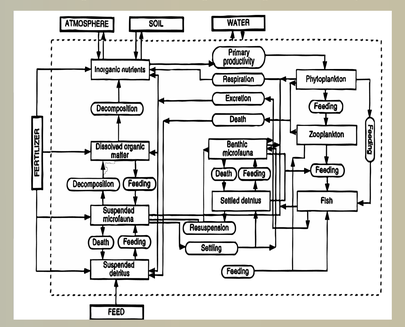
Non-fed techniques-

Non-fed aquaculture production systems do not depend on the addition of fish-feed and instead rely on natural food productivity (plankton and algae) for consumption by aquatic organisms (fish). Pond fertilization is used to enhance natural food production within the pond. To maintain adequate production of natural food to support desirable fish yields, it is important to remember three primary requirements: sufficient fertilization, sufficient sunlight, and favorable water temperatures. Phytoplankton serve as the base of the pond food chain and use the nutrients in fertilizers and energy from the sun for photosynthesis, producing oxygen as a byproduct.

Polyculture, aquaponics, and integrated aquaculture-

Sustainable aquaponics and integrated aquaculture seek to biodivesify farming practices by involving the co-cultivation of complementary species using a carrying capacity approach. These integrated farming practices hold significant promise for improving productivity, profitability, and household diets, as well as helping to mitigate some of the externalities associated with monoculture.

Conceptual model of pond aquaculture system.



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