Sustainable Aquaculture: Protecting Our Oceans and Feeding the World

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Aquaculture’s Time Has Come

The sustainability of aquaculture will not be a choice for the future, but a necessity. Aquaculture has grown from an alternative means of producing marine and freshwater plants and animals to an integral part of the existing food supply and, in fact, the most promising means of supplying the protein that the world will require to feed its growing population.

Over the last 30 years the world has seen changes in fishing technologies/effort that have facilitated our ability to extract fish and other aquatic organisms from the sea, lakes, and rivers at a rate never before experienced. As the world population has continued to increase so has the demand for aquatic protein and therefore our ability to sell ‘all that we can catch’, or extract from these aquatic environments. As we continued to extract at a rate greater than is biologically sustainable, we are faced with a diminished resource base and overfished species. Embracing terms such as maximum sustainable yield, countries began to implement quotas on fishing effort and gear and/or restrictions to entry. There were warning signs that the ‘supply’ was being ‘fished out’. Today, of all the known commercial species being fished, only 15 percent are at a level that will allow for additional harvesting. This is not sufficient to keep up with demand. In fact, there has been little ‘new’ fish biomass extracted from our oceans since the 1980s.

In terms of global production volume, that of farmed fish and aquatic plants combined surpassed that of capture fisheries in 2013. In terms of food supply, aquaculture provided more fish than capture fisheries for the first time in 2014. By 2014, a total of 580 species and/or species groups were farmed around the world.1 In 2014, 73.8 million tonnes of aquatic animals were harvested from aquaculture (Table 1).2

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1 Food and Agriculture Organization of the United Nations (FAO), The State of the World Fisheries and Aquaculture (Rome: FAO, 2016), 22, http://www.fao.org/3/a-i5555e.pdf.
2 Id., p. 5.
As the supply of wild caught fish/seafood has plateaued, the world population growth in absolute numbers is at a point where protein demand will greatly exceed supply. We have reached a critical juncture in history, where the world needs to find alternative food sources that can be supplied and increased in an environmentally sustainable manner.

### Sustainability Requires Change

All food production requires inputs such as food, water, energy, and physical space. The key is to find food production systems that have the highest yields of output for the least amount of inputs (resources), i.e., are the most efficient in terms of resource use.

The art of culturing fish for consumption began in China over 3,000 years ago. Today, China is the world's leader in fish production in terms of biomass, with most of this production based on the culture of freshwater fish (carp). The majority of this production is consumed locally. Carp are an excellent fish for culture as they are largely herbivores and can be grown without the need for fish-based protein diets.

Why does this matter? Fish feed is widely regarded as becoming a major constraint to the growth of aquaculture production in many developing countries. The culture of non-fed animal species in 2014 represented 30.8 percent of world production of all farmed fish species. The most important non-fed animal species include (i) two finfish species, silver carp and bighead carp, typically in inland aquaculture, (ii) bivalve molluscs (clams, oysters, and mussels, etc.), and (iii) other filter-feeding animals (such as sea squirts) in marine and coastal areas. Growth in production, however, has been faster for fed species than for non-fed species.³

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³ Id., 25.

### Table 1  Breakdown of aquatic animals harvested from aquaculture

| Type      | Harvested (million tonnes) | Percent |
|-----------|---------------------------|---------|
| Finfish   | 49.8                      | 68      |
| Molluscs  | 16.1                      | 22      |
| Crustaceans | 6.9                  | 9       |
| Other     | 7.3                       | 1       |
| Total     | 73.8                      | 100     |
The Western world has, over the last decades, focused its seafood diet on primarily four seafood types, namely shrimp, tuna, salmon, and cod. Shrimp and salmon have been widely cultured for over 40 years now. With the loss of the commercial cod fishery stocks, aquaculture of this species has begun in several countries driven by existing demand. The culture of tuna (bluefin) has only recently ‘cracked the technology’ enabling the entire lifecycle to be replicated in captivity. There has always been a strong market for tuna, and the culture of it will relieve the pressure on wild stocks. But is the culture of these species ‘sustainable’? All of these species require a diet that incorporates a protein that is presently derived from fish, primarily in the form of fishmeal. If aquaculture is to expand and fill the protein supply gap for the world then it cannot depend on fishmeal-based diets that are dependent upon the catch of wild fish. The answer lies in the production of fish that can be grown on plant-based diets, i.e., herbivorous/omnivorous fish or finding suitable fish protein replacements that can be derived from sustainable sources.

Initiatives have been undertaken to replace fishmeal in fish diets with soy and other plant-based proteins. Those fish that have evolved to utilize fish-based proteins for growth can withstand various levels of protein replacement, but ultimately growth and fish health is threatened when levels are exceeded. Commercial initiatives have recently begun for the culture of insect larvae, namely soldier fly larvae for the production of a larval meal. The soldier fly larvae are produced by growing soldier flies on pre-consumer food waste collected from urban centers. Thus, a ‘waste’ product is being used as a food source to produce what becomes a food source for a product (fish) that we can then consume. A 2014 review of insect feeding trials by the Food and Agriculture Organization of the United Nations found that fish common to aquaculture, like tilapia, could safely have between 25 and 100 percent of the soymeal or fishmeal in their diets replaced with insect meal with no negative consequences to fish production. Even when cooked, the fish showed no changes to aroma, taste, or texture. There has also been preliminary research done on the use of other marine organisms at a lower trophic level, which are a direct replacement for fishmeal proteins and can be grown on organic wastes.

Changes to fish feed protein supplies are not the only change that will be required to allow aquaculture to expand. The world must examine its eating behaviors which not only impact resource use but also overall health of societies. In addition, food production systems, including the production of aquatic foods, must be examined in light of long-term sustainability and

4 M. Glassman, “Feeding 2050: Sustainable Aquaculture and the Future of Protein,” The Chicago Council on Global Affairs, 7 June 2017, https://www.thechicagocouncil.org/blog/global-food-thought/feeding-2050-sustainable-aquaculture-and-future-protein.
'production efficiency'. Some aquaculture practices use the label ‘sustainable’, but not all of the resources used are accounted for, especially if wastes are being absorbed by the local environment. Life-cycle analysis takes a broader view and can be used to assess and rank the sustainability from a more holistic viewpoint.

In order for the benefits of aquaculture to be realized, it must be sustainable from both an environmental and economic perspective. This will undoubtedly mean that the world will have to change its dietary habits and begin to consume proteins that are more efficient in their resource use. However, a balanced diet includes other foods than just proteins.

There has been a growing interest in the integration of agriculture and aquaculture. When these two food production systems are combined, the result is a food production system that is extremely efficient in terms of its resource use. In Asia, rice farmers are integrating freshwater fish culture into their irrigation systems to reduce predatory snails. The result is a gain in fertilizer nutrients from fish wastes and harvesting the fish to add income to their crop. The waste from fish production has been found to be an excellent source of nutrients for plant production.

Production systems that combine aquaculture with hydroponic plant culture are termed ‘aquaponics’. Aquaponics can be done at any scale and is one of the most efficient uses of land and water when producing fish and food crops. Aquaponic systems use 90 percent less land and water than traditional field crops. In addition to being efficient resource users, aquaponic systems are ‘natural’ by design and do not use insecticides or antibiotics. Aquaponic systems produce higher yields than field crops and greenhouse hydroponic production systems. It can be said that the integration of fish and plant production is the most efficient food production system on the planet. These same levels of efficiency are also realized in water usage.

When examining food production systems one must examine production parameters such as food and water conversion ratios, i.e., how efficiently the animal being produced converts its food and water into edible protein. In addition, to curtail practices that contribute to global warming one must consider the greenhouse gas emissions related to the production system being used.

Fish process energy more efficiently than mammals such as cows and pigs because they are cold-blooded (so less calories are needed for warming themselves) and live in water (so relatively more of the body converts to muscle than bone). Cultured fish score a ‘low’ rating with respect to relative greenhouse gas emissions.5

5 “Protein Scorecard,” World Resources Institute, April 2016, http://www.wri.org/resources/data-visualizations/protein-scorecard.
Aquaculture Expansion

Aquaculture began with the development of fish/plant culture in earthen ponds with flow-through or tidal water exchange from rivers and/or oceans. Because fish farming involves the active and daily input of humans, we tend towards developing them in areas where human access is easier, i.e., nearshore, but with the continued growth of the aquaculture sector, the utilization of nearshore sites for cage culture has resulted in ‘conflict of use’ and environmental pollution issues. Both of these have resulted in private and public opposition to the expansion of aquaculture.

This has led to the speculation that aquaculture growth will occur increasingly either offshore⁶ or onshore (inland and land-based facilities). Land-based facilities (especially those practicing recirculation) have a reduced risk for disease exposure and are not exposed to varying temperatures and/or predators. Land-based facilities are easily monitored, do not require sea-going vessels to transport product, and can have a high degree of predictability that favors investment and market penetration. For these reasons and others, a strong case can be presented that will see expansion of the aquaculture sector taking place on land. Technologies exist that will permit the production of both freshwater and marine species independent of water sources. This allows aquaculture production facilities to be located in close proximity to urban centers, thereby further reducing the carbon footprint by avoiding extensive transportation routes.

Land-based fish farms require a continuous supply of energy to produce oxygen and run pumps and other equipment. To be truly sustainable this energy supply must come from renewable sources. A good fit for land-based fish farms would be operation of air compressors on solar power, with compressed air stored and used to generate electricity continuously. Compressed air is also used as a source to generate the oxygen requirements for the farms.

Conclusion

In 2015, the United Nations member states adopted the 2030 Agenda for Sustainable Development. The Agenda includes a set of seventeen Sustainable Development Goals (SDGs). SDG 14 expressly focuses on the oceans, underlining the importance of the conservation and sustainable use of the oceans and seas and of their resources for sustainable development, including through their contributions to poverty eradication, sustained economic growth, food

⁶ See Soto and Wurmann’s essay on offshore aquaculture in this volume.
security, and creation of sustainable livelihoods and decent work. Sustainable aquaculture can play an important role in achieving SDG 14.

Aquaculture has the ability to supply the world’s protein, but it will require shifts in our patterns of resource use, eating habits, and continued development of technologies that allow for improvements in production efficiencies. Sustainable aquaculture will not only feed the world, but offer the needed protection and conservation of the world’s ocean resources.

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7 FAO, FAO and the 17 Sustainable Development Goals (Rome: FAO, 2015), http://www.fao.org/3/a-i4997e.pdf.