Making the Most of Fish Farms

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When most people hear the word 'fish,' they think of food. In 2009, the Food and Agriculture Organization (FAO) of the United Nations reported world consumption of fish at 117.8 million tons, up more than fifteen million from 2004 (FAO, 2009). Fish, to all but the most dedicated ichthyologist, are represented primarily by dish, taste, and breed: salmon, Atlantic cod, tuna, and the like.

However, the prospects of fish as a means of feeding a growing world population are beginning to look more and more perilous. By now, most educated citizens have some idea of the devastation overfishing has caused on wild fish stocks. Overfishing – or harvesting more fish than natural reproduction can sustain – has been prevalent on a global scale for decades, but only recently has the collapse of fish stocks worldwide drawn widespread political attention. Aquaculture – the farming of marine species (primarily fish, but also crustaceans, sea plants, and other marine organisms) – offers a possible alternative to traditional capture, one that could not only ease the burden on wild fish populations, but play a significant role in feeding a growing world population.

Figure 1. Nile tilapia, a popular aquaculture fish breed.

Despite its promise, however, aquaculture in its current state is far from the perfect solution to providing fish to the world both sustainably and economically. The environmental impact of fish farms as well as the pitfalls of economic inefficiency demand that aquaculture be inspected with a discerning and skeptical eye. Aquaculture on an industrial scale is still a relatively new phenomenon, and monitoring its impacts – both the obvious and hidden – is a responsibility that both potential fish-farmers and policymakers ought to assume.

Different fish species are chosen for aquaculture for a variety of reasons, from taste and economic value to hardiness and ease of growth. Of fish species, tilapia is rising as a strong contender for the title of the most popular and aquaculture-viable strain (Bradford, 2011). Similarities in taste and texture between tilapia and Atlantic cod – one of the most popular and heavily overfished fish species consumed today – make tilapia meat a viable substitute for the overfished cod in most cases, and is therefore growing in market value. More critically, however, tilapia is both hardy and easy to grow, with a flexible diet and relatively high tolerance to environmental factors such as salinity and temperature.

> "Aquaculture offers a possible alternative to [...] capture"

That said, the very qualities that make tilapia such a highly valued aquaculture fish make it an extremely potent invasive species. High rates of reproduction and growth, paired with a tolerance to everything but the lowest temperatures, make Mozambique tilapia – the most common strain of farmed tilapia found today – dangerous invaders in tropical and subtropical environments; additionally, tilapia exhibit strong parental care that includes housing young in the parent's mouth, granting tilapia spawn a far greater range of mobility than that of other fish breeds (Costa-Pierce, 2003). Due to these factors, invasive tilapia have already penetrated ecosystems in Florida, California, and elsewhere, outcompeting native species and presented a serious threat to native biodiversity. For this reason, fish farmers in the United States are seeking to replace the Mozambique strain with Nile tilapia, an easier-to-raise, less aggressively invasive variety. Furthermore, genetic manipulation of aquaculture species targets the precise traits that make fish strains better invaders: increased growth rate, size, and reproductive ability.

In addition to threatening ecosystems, aquaculture also raises a significant question about its economic efficiency. If aquaculture is to be marketed as the sustainable alternative to wild capture, policymakers will need to interrogate how fish farms actually utilize their resources. This question is especially pertinent when considering the farming of salmon, a highly valued aquaculture fish due to its popularity in North American and European cuisine.

Unlike plankton-eating tilapia or bottom-feeding catfish, salmon are carnivorous, meaning salmon farmers need to invest resources in "feed fish" (raised solely for the purpose of feeding other fish) to raise their expensive animals. In 2002, 46% of all fish meal and 81% of all fish oil harvested was cycled back into aquaculture, rather than put towards directly feeding humans (Diana, 2009). Biologically, this process is highly inefficient, as only 10% of the energy and biomass passes on between trophic levels, or positions along the food chain (grain lies below rats, which lie below snakes, and so forth). This principle is part of the reason why meat is a luxury good: a pound of beef requires approximately ten pounds of feed – corn, grass, or otherwise – to produce. This same trophic law applies to raising salmon, and salmon farmers either turn to utilizing more land and resources to raise feed fish or resorting to wild capture, solely because salmon meat is valued so highly.

In addition to poor resource management, disease and parasites also create problems in aquaculture. Like in industrial chicken coops and cattle factory farms, disease and parasites are a large health risk due to the high concentration of animals in a small area. Marine disease and parasites are far more likely to infect wild fish populations both within and outside of the fish farm due to the proximity and ease of transfer between farmed and wild fish via waterways and water runoff from fish farm pools (in contrast, there are no real wild cattle in the United States, meaning an outbreak of disease within a factory farm is less likely to impact nearby ecosystems). These threats are very real, as disease outbreaks among tiger shrimp in the mid to late '90s forced shrimp farmers to switch to different species and breed for hardier shrimp species (Diana, 2009). Far more terrifying, however, are the reports of the first outbreak of infectious salmon anemia (ISA) in the Pacific Northwest, a high-mortality disease first reported in a Norwegian fish farm in 1980 and until now contained to only aquaculture. ISA is both devastatingly pervasive and costly, killing huge swathes of fish and requiring huge amounts of money to control. In New Brunswick, Canada, recurring ISA outbreaks results in losses of up to $5.5 million dollars a year, while a 1998-1999 epidemic in Scotland cost $32 million to eradicate. With the first confirmed cases of ISA in the Pacific Northwest, the unique dangers of high-intensity fish farming suddenly becomes far more harrowing (Center for Food Security and Public Health, Institution for International Cooperation in Animal Biologics, 2010).

As with traditional farming, fish farming can be land-intensive; prime fish farm territory often overlaps with areas of ecological importance such as mangrove swamps and wetlands, while nutrient-rich fertilizer and waste runoff from fish farms can disrupt the chemical balance of surrounding waterways, causing deadly algal blooms that suffocate marine ecosystems (Diana, 2009). Beyond these issues, as the aquaculture industry grows, previously unheard of issues may begin to crop up,

Figure 2. A fish farm in Fuzhou, China. China has produced more than half of the world's aquacutlure-produced tilapia since 1997.

simply due to the fact that such large-scale aquaculture has not yet been fully developed. While fish farming can help provide a more sustainable alternative to wild fish, the 'sustainability' – both environmental and economic – stems on careful and knowledgeable implementation, as the damage poorly conducted aquaculture threatens is very real.

If aquaculture is to be both a reliable food source and sustainable alternative to wild capture, it needs to be implemented responsibly; the snags and dangers of irresponsibly fish farming have already manifest themselves in uncontrolled invasive species, disease outbreak, , and damage to ecosystems. Despite the dangers and problems associated with irresponsible implementation, however, aquaculture does have the opportunity to play a role in creating a more sustainable global food supply chain.

Similar to the raising of other livestock, raising fish on a mass scale requires both large influxes of nutrients – either through feed fish or by fertilizing ponds to stimulate plankton growth – and waste removal to ensure animal health. Currently, many fish farmers use non-organic fertilizers designed to promote plankton growth for fish such as tilapia, and dispose of waste simply by releasing contaminated pondwater into nearby water systems, a significant environmental problem. Some farmers, however, have turned to the manure of other livestock and fish to fertilize fish ponds; not only is this practice less expensive for farmers without access to more expensive industrial fertilizers, but using the waste products of other animals such as chicken or pigs turns waste products into useful agricultural tools (Muendo, 2006). Raising two fish in tandem – for instance, catfish and tilapia – also has been seen to produce tangible benefits, as catfish waste stimulates plankton growth for tilapia to feed on and improves water quality, reducing the need for both industrial fertilizer and health-related costs such as antibiotics (Lin, 2003).

Besides feeding other fish, aquaculture waste can also be used to fertilize terrestrial crops such as rice. Fish waste is prime fertilizer due to its high phosphorous and nitrogen levels, both of which are limiting nutrients that are often provided by industrial fertilizers; growing rooted aquatic plants in fish ponds allows farmers to store those nutrients in plant form, and eventually harvest and use those plants to fertilize other, more valuable crops (Lin, 2003). In Vietnam, rice-fish dual farming is a common practice today, with fish raised directly in the fields where rice is grown. While this joint agricultural practice does benefit the health of the plants mildly (swimming fish stir up sediment and increase nutrient availability), the primary benefit of this sort of farming is efficiency: rice farmers who raise fish alongside their rice crop gain a valuable source of supplemental nutrition or income at little cost (Vromant, 2001). By using techniques like fish-rice dual farming and waste recycling, aquaculture can fill a unique niche in global food production as a sustainable and integrated practice.

More so than any other factor, the promise of aquaculture lies in its unknowns. While there are clear dangers associated with irresponsible practice, the true potential of aquaculture remains unexplored. To draw a comparison, consider traditional agriculture. Early innovations such as crop rotation and efficient irrigation took generations to develop, while the green revolution of the mid-twentieth century produced a huge boost in yields and played a significant role in permitting the current trends in population growth. Aquaculture, which has only recently been pushed towards industrial-scale, remains full of unexplored possibilities and efficiencies. Many potential aquaculture species are either undeveloped or even unknown: the replacement of Mozambique tilapia by Nile tilapia due to key differences in ease of growth and invasive qualities is just one example of how fish farmers are continuing to push the boundaries of their trade. New studies are published every year on increasing pond health, benefits of dual-raising fish, and the various minutiae of fish ecology that will constantly improve aquaculture's ability to both relieve pressure on natural ecosystems and provide food to the world. Aquaculture's role role in the future of food is unquestionable. Moving forward, however, will require wisdom, caution and – most importantly – informed and eager optimism.

REFERENCES

1. Bradford, M. (2011). The biology and management of Tilapia mariae (Pisces : Cichlidae) as a native and invasive species: a review. Marine and Freshwater Research, 2011, 62(9), 902-91.
2. Center for Food Security and Public Health, Institution for International Cooperation in Animal Biologics. (2010). Infectious Salmon Anemia. Ames, IA: Iowa State University.
3. Costa-Pierce, B. (2003). Rapid evolution of an established feral tilapia (Oreochromis spp.): the need to incorporate invasion science into regulatory structures. Biological Invasions 5(1-2), 71-84.
4. Diana, J. (2009). Aquaculture production and biodiversity conservation. Bioscience, 59(1), 27-28.
5. FAO. (2009). Overview: Major Trends and Issues. United Nations.
6. Lin, C. Yi, Y. (2003). Minimizing environmental impacts of freshwater aquaculture and reuse of pond effluents and mud. Aquaculture, 226(1), 57-68.
7. Muendo, P., Milstein, A., El-Naggar, G., Stoorvogel, J., Verdegem, M (2006). Exploring the trophic structure in organically fertilized and feed-driven tilapia culture

environments using multivariate analyses. Aquaculture Research, 2006, 37(2), 151-163

8. Vromant, N., Chau, N., Ollevier, F. (2001). The effect of rice-seeding rate and fish stocking on the floodwater ecology of the trench of a concurrent, direct-seeded rice-fish system. Hydrobiologia, 457, 105-117.

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