Executive Summary: Environmental Footprint Literature Review

Land-Based Aquaculture

Aquaculture is the fastest growing food production sector globally. The United Nations Food and Agriculture Organization (FAO) sees little possibility to increase supply from wild capture fisheries to meet the growing demand for fish protein, as 75% of the world's fishing grounds are fully exploited, over exploited or severely depleted. Despite declines in wild fishery production, global demand for seafood continues to grow, and land-based aquaculture is slated to see continued growth to meet increased market demand. In this context, some systems of marine aquaculture production, especially for high value species, are moving towards land-based farming, enabled by technological equipment for water re-circulation. The mainstay of U.S. land-based aquaculture is the production of channel catfish, which occurs largely in earthen ponds in southeastern states, and oysters, which occurs in coastal areas. The U.S. is also the leading global importer of fish and fishery products. Ninety-one percent of the seafood we eat (by value) is imported, half of which is from land-based aquaculture.

Roughly half of the current global aquaculture production in terms of total harvested tonnage occurs in marine environments, such as fish raised in net pens or near-shore cages, or shellfish grown in bottom culture bags and rack bag systems. The focus of this summary, however, is to summarize life cycle assessment (LCA) research on the environmental impact of land-based aquaculture production systems. These studies can help identify the aspects of land-based aquaculture production that most contribute to environmental impacts, as well as potential trade-offs between impact categories. Such lessons can be useful in informing both developers of land-based aquaculture systems and selective buyers of land-based aquaculture products. The vast majority of studies focus only on impacts within the growing system, hence the downstream stages of processing through consumption are not covered in this review. Fish species represented in the reviewed studies include Atlantic salmon, rainbow trout, Arctic char, turbot, African catfish, tilapia, sea bass, common carp, tench, roach, perch, sander, and pike.

Key Findings

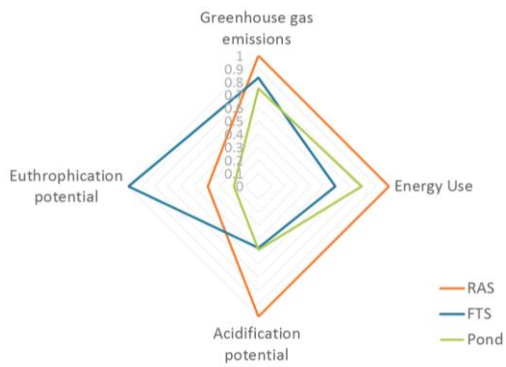
Potential benefits of land-based fish farming systems include minimized threats of cultured fish escaping and competing with wild populations, improved control of diseases and parasites, true management of water quality (temperature, oxygen rate, nutrient and suspended solids content), and better control of nutrient releases to the environment. Challenges include high capital costs, increased energy demand and operational costs, and potential for rapid chemistry alterations, which requires continuous monitoring. The three typical production systems in use include:

- **Recirculating aquaculture system (RAS)** – Closed systems, commonly tank based, in which water is processed to remove suspended solids and nutrients, and re-used. These systems have high energy use for pumping and filtering water, but are typically modular, and hence, are scalable and can be located nearly anywhere, including urban environments.
- **Flow-through systems (FTS)** – These commonly take the form of raceways or tanks with a one-time flow through of water with varying degrees of input and output water treatment methods. Water sources include river flows, well

water, or water pumped from a nearby coast. Compared to RAS, water use is high and nutrient releases are more challenging to control, but pumping energy needs are typically reduced.
- **Pond systems** – Possibly the earliest and most natural form of LBA, these consist simply of earthen or lined ponds or ditches, often using ecological processes to manage water quality.

The chart to the right shows a comparative overview of the environmental impacts per kilogram of fish produced by the dominant LBA systems, shown as an average of studies reviewed. In general, RAS have greater on-site energy demand, primarily electricity, than FTS because of pumping needs. This can reflect in higher energy use per kilogram fish, as well as higher carbon footprint and acidification potential. Due to the flow through aspect of FTS nutrient releases tend to be higher than both RAS and Pond systems, which is reflected in the eutrophication impact category. Feed production is another important contributor to nearly all environmental impact categories. Because of the general importance of feed, the amount of feed per kilogram of fish produced is also a strong determinant of a system's environmental impact.

Relative comparison of impacts for the three main aquaculture systems per kilogram of fish yield



Feed

The supply of feed remains one of the more controversial, and environmentally impactful aspects of land-based aquaculture. Historical perception has been that production of high value carnivorous fish such as salmon and trout requires feed containing fishmeal and fish oil, thus linking land-based aquaculture to wild fishing industries that may not be sustainable. In the past, because modern commercial fishing techniques generated significant by-catch, such fish-based aquafeeds were the most economical option. One study in 2009 demonstrated that the ratio of wild fisheries inputs to farmed fish output was 0.63 for the aquaculture sector as a whole (globally) but remained as high as 5.0 for farmed Atlantic salmon. Aquaculture's share of global fishmeal and fish oil consumption has risen substantially, as greater amounts of fishmeal are fed to omnivorous species, and high levels of fish oil are used to provide long-chain omega-3 oils in farmed fish. A number of LCA studies reviewed have found tradeoffs between impact categories when fish-based feeds are substituted with plant-based feeds.

Several studies have compared different types of feeds against each other, and have come to competing conclusions. In some studies, shifting from fish-derived ingredients to plant ingredients does not reduce energy or other environmental impacts (except for net primary production), but other researchers have documented the potential for energy savings and environmental benefits from using plant oils in lieu of fish oils. The general conclusions among these studies are that feed impact is highly dependent on source, and impacts of feed types, whether fish- or plant-derived can vary widely.

Conclusions

As wild fisheries diminish and demand for seafood continues to grow, land-based aquaculture is a promising production method with wide-ranging applicability. This review of existing LCA literature concludes the following:

- Much of the environmental impact of recirculating aquaculture systems is linked to electricity use. Thus, utilizing renewable electricity generation can significantly reduce the environmental footprint.
- Generally speaking, recirculating aquaculture systems have lower eutrophication impact than flow-through systems because low flow rates and high concentrations make nutrients easier to manage.
- Feed is an important driver of land-based aquaculture's environmental impact. While there is strong need to reduce wild fishery inputs to aquaculture feed, replacement with plant-based alternatives does not necessarily result in reduced environmental impacts in all categories.

The full report created by Center for Sustainable Systems - University of Michigan can be downloaded from http://www.oregon.gov/deq/mm/food/Pages/Product-Category-Level-Footprints.aspx.