Aquaculture in China: 
Challenges and Opportunities

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Introduction

Aquaculture—the farming of aquatic plants and animals—is the world’s fastest growing food production system. In 2014, aquaculture surpassed wild-caught fisheries in its supply of seafood products for human consumption. The production from capture fisheries leveled off in the 1980s and has remained relatively static ever since (FAO, 2016). The reason: there simply aren’t many more fish left in our oceans. Today, 89.5% of wild fish stocks are overfished or fully-fished (FAO, 2016). Aquaculture has stepped up to meet the increasing demand, supplying the world in 2014 with almost 74 million tons of seafood—compared to the 70 million tons of wild-caught seafood for human consumption—amounting to over half of all seafood consumed. Due to reduced waste, improved distribution, expanded production, and many other factors, the growth of world fish supply for human consumption over the past fifty years has doubled that of population growth1 (FAO, 2016).

Although aquaculture will remain one of the fastest-growing food production systems, its growth rate is projected to slow over the next decade from 5.4% annually to 3% annually. This anticipated slowdown will be due to: “constraints on the availability and accessibility to water of good quality; competition from alternative uses for optimal production locations; availability of fish seeds and feeds in the requisite quality and quantities; insufficient investments in infrastructure in regions endowed with natural resources for aquaculture production; capital constraints; and challenges in governance and regulatory framework.” (FAO, 2016). Despite this projected slowdown in growth, aquaculture is nevertheless a massive, and relatively young, food production system that ought to be monitored closely.

China: A snapshot

China has been, and continues to be, the epicenter of aquaculture. The FAO calls China the “cradle of the beginning of aquaculture,” having farmed the common carp for some 4,000 years (Rabanal, 1988). Today, China is the world’s largest fish producer both from wild-caught fisheries and from aquaculture; the third largest importer of seafood; and is experiencing significant growth in seafood consumption (FAO, 2016). In 2014, China produced 45.5 million of the 73.8 million tons of farmed aquatic animals, or more than 60% of global farmed fish production (Ibid).2 The graph below (Figure 1) shows the volume of aquaculture production globally from 2002-2012, clearly demonstrating how important China, and all of Asia-Pacific, is in terms of fish farming.

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1 3.2% from 1961-2013, compared with 1.6% world population growth over that same time period.
2 China was the main producer of fish from capture fisheries that year as well. Other major aquaculture producers include Indonesia (5.77%), India (6.62%), Viet Nam (4.6%), Bangladesh (2.65%), and Egypt (1.54%). If China is excluded, aquaculture produced 33% of fish for human consumption in 2013, up from ~%15 in 1995, meaning the growth of the aquaculture industry is significant even outside of China.
Chinese per capita fish consumption exhibited an annual growth rate of 5.0 percent between 1993-2013 (FAO, 2016). In fact, for the fifty-year period between 1961-2011, the daily fish intake of China quadrupled, making China the largest fish consumer in the world (Villasante et al., 2013). Given the scope of Chinese production and consumption, understanding the role China plays in aquatic agriculture is of global relevance.

China’s aquaculture production is unevenly distributed between its twenty-three provinces. Freshwater aquaculture accounts for 90.8%\(^3\) of Chinese aquaculture production, and the five largest provinces for freshwater production are Hubei, Guangdong, Jiangsu, Hunan, and Jiangxi (see Figure 2) (Wang et al., 2015). Carp make up the most species of fish farmed in freshwater (the most farmed finfish in China by volume include grass carp, silver carp, common carp, bighead carp, crucian carp, and then tilapia).

Over half (54.9%) of all farmed aquatic species in China are non-fed, meaning they are primarily filter-feeders who do not require external feed input, and more than 82% of freshwater finfish farmed in China are non-fed (Han et al., 2016). Ethical\(^4\) and environmental concerns about the use of fishmeal, while existent, are not as poignant as they are for other geographies with higher fishmeal inputs—namely, geographies that farm carnivorous finfish, like salmon farming in Norway, Chile, and other European countries.

One group of non-fed, low trophic level, aquatic animals farmed in China worth highlighting is bivalves. In 2014, China farmed 12 million tons of bivalves—more than 25

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\(^3\) Not including the farming of molluscs or algae.
\(^4\) The extent to which Chinese consumers themselves have ethical concerns about any aspect of animal use in farming practices is unclear. One survey of over 6,000 respondents across 29 of the 34 regions in China paints a dim picture: only a little more than one third of respondents had ever heard of ‘animal welfare’; over seventy percent view animals instrumentally as tools for consumption; and less than eight percent believe animals should have some basic rights (You et al., 2014).
percent of China’s total aquaculture production—which accounted for five times the number of bivalves farmed by the rest of the world (FAO, 2016). Many believe that whether we ought to have aquaculture at all remains an open question. However if aquatic farming practices must exist, then compared to the other ~500 aquatic species current farmed, bivalves appear to be best in terms of ecological, food security, and animal welfare impacts (Jacquet et al., 2016).

Figure 2: Top fifteen ranked Chinese provinces for finfish and crustacean aquaculture production (average from 2000-2014) and the percent contribution of each province to the total Chinese aquaculture production. (Source: Han et al., 2015, page 3, figure 1).

The following four trends related to Chinese aquaculture warrant consideration if we hope to help engender a healthy, sustainable, and humane aquatic food system: fish feed inputs, dependence on antibiotics, domestication rates, and climate change.

Fishfeed to feed fish
Farmed animals must be fed to grow. Farmed fish are fed fishfeed which contains the vitamins, minerals, oils, and proteins necessary for their growth. Herbivorous and omnivorous fish eat a feed mixture that often involves plant proteins (from corn or soy) and vegetable oils. Carnivorous fish are fed feed that contains fish-based oil and protein (fish oil and fishmeal, respectively). The fish processed into fish oil and fishmeal are mainly smaller forage fish (like anchovy, sardines, herring, etc.).

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5 According to NOAA, three-quarters of fishmeal is produced from small, open-ocean (pelagic) fish with short life cycles. The other one-quarter is produced from by-products of when seafood is processed for human consumption.
China imports more fishmeal than any other country in the world, bringing in one-third of the world’s fishmeal trade annually (FAO, 2016). In 2012, Chinese aquaculture imported an estimated 1.4 million metric tons (mmt) of fishmeal (~6.7 mmt of live-weight fish) (Cao et al., 2015; Shepard & Jackson, 2013). China is also increasingly a major fishmeal producer. Between 2000 and 2014, Chinese production of fishmeal grew by 272.5% (Han et al., 2016).

Despite these startling numbers, a debate exists about the extent to which fishmeal and fish oil is used in Chinese aquaculture systems. One study used primary survey data from three provinces in China to analyze the use of fishfeed in the carp and tilapia sectors (the two most farmed fish species in China). The result: “virtually all carp and tilapia farmers in [their] survey regions use manufactured feeds containing fishmeal” (Chiu et al., 2013). The scale of China’s reliance on feed containing fishmeal and fish oil may be a serious issue given that such dependence pressures wild fish stocks, challenges the extent to which aquaculture can be considered sustainable to any degree, and greatly increases the number of individual animals killed by this agricultural practice.

Notwithstanding the almost 300% increase in aquafeed production in China since 2000, the fishmeal used in that feed has remained relatively stable (Han et al., 2016). In other words, the amount of food China uses to feed its farmed fish is increasing significantly, but the amount of fish used to make that food is not increasing (see Figure 3).

**Figure 3**: Trends in global fishmeal and fish oil production compared to global and Chinese aquaculture production of finfish and crustaceans. (Source: Han et al., 2015, page 5, figure 5).

How? “In the past few decades, increased knowledge on the digestive processes and nutritional requirements of farmed species and the processing of raw material together with the use of alternative proteins has led to an impressive reduction in fishmeal inclusions in aquafeeds
as well as feed conversion ratios in cultured species in China.” (Han et al., 2016, p. 5). In fact, China supplies 38% of the world’s fish, but it only uses 25-30% of the world’s fishmeal, meaning aquaculture systems that farm higher trophic level fish are more harmful relative to their output (Han et al., 2016). The stable rate of fishmeal and fish oil use is a good thing from a sustainability, food security, and animal welfare perspective. This does not mean that Chinese fish farming is sustainable or humane; it simply means that there are relatively worse systems elsewhere in the world.

**Hooked on antibiotics**

The negative externalities caused by terrestrial agriculture's reliance on antibiotics is well documented. Given that farmed fish only surpassed wild-caught fish in the amount supplied for human consumption in 2014, conversations about seafood have only recently begun to address the use of antibiotics. One recent meta-analysis reviewed over 650 papers examining the similarities and differences between terrestrial and aquatic farming practices and found that 76% of the antibiotics used in farming are of importance in human medicine; six classes of those antibiotics are listed by the World Health Organization as critically important/highly important/important antimicrobials; and finally that bacteria displayed identical resistance mechanisms in both terrestrial and aquatic farming practices, meaning aquaculture is contributing to the same resistance problems for which land-based agriculture has been so widely criticized (Done et al., 2015). This should not be surprising, as terrestrial and aquatic environments are not radically different in their natures. As Cabello (2006) writes:

> The commonality of antibiotic resistance determinants and of genetic elements between aquatic bacteria, fish pathogens and bacteria from the terrestrial environment strongly supports the concept that antibiotic usage in aquaculture will influence the appearance of resistance in bacteria of other niches, including resistance in pathogens able to produce a variety of human and animal diseases.

The concern about antibiotic use in aquaculture broadly is applicable to aquaculture in China specifically. A 2017 review of the use, residue, and human health risk of antibiotics in Chinese aquaculture found that twelve of the twenty antibiotics administered were not authorized for use (Liu et al.). Over two hundred diseases have been found in aquacultured species in China (Wei, 2002). In 2016, the Food and Drug Administration (FDA) issued an alert on the presence of antibiotics in Chinese aquaculture products imported into the United States. In 25% of the imported aquaculture products from China, the FDA found residue of drugs that “are unsafe food additives” which “would render the food adulterated” (FDA, 2016).

Notwithstanding the evidence above, some research suggests that, compared to its terrestrial counterpart, Chinese aquaculture is not very concerning in terms of antibiotic use. At least one study reviewed the use of veterinary medicines in Asian aquaculture to find that antibiotics were used prophylactically only 5% of the time, and generally did not exceed
recommended dosages (Rico et al., 2013). Henriksson (2015) paints an optimistic, yet cautionary, picture:

> With an unarguably turbulent past and with reservations for still problematic sectors, aquaculture overall offers a source of animal proteins with relatively limited antimicrobial use. Aquaculture may, however, have larger environmental discharges and side-effects on aquatic ecosystems, whereas livestock has larger effects on soil biota. The industry should therefore continue to strive toward alternative and better practices.

One reason antibiotic use may not be as rampant is that much of the farmed fish in Asia still retain enough genetic diversity to have robust immune systems. Antibiotic use will likely increase significantly as farmed fish go through selective breeding to meet their high demand, decreasing genetic variance and therefore increasing the threat of parasites and disease. So the extent to which antibiotics become a greater environmental, health, or animal welfare issue will depend in part on how quickly farmed fish are genetically altered.

**Domestication and genetic improvement**

The rate by which we are domesticating and genetically ‘improving’ fish is unprecedented. About 9,000 years ago, humans began domesticating sheep for food. About 2,000 years ago, we started domesticating chickens. The domestication and selective breeding of fish, however, dates back only to the 1970s. Domestication not only involves controlling the lifecycle of a species, but also involves manipulating that lifecycle to produce genetically ‘improved’ organisms. Genetic improvement programs for carp were introduced in Asia in the 1970s (Dong et al., 2015; Ninh et al., 2013) and tilapia in the 1990s (Kobayashi et al., 2015).

Unlike land-based animal agriculture, less than 10% of aquaculture production comes from selectively bred, domesticated fish stocks (Gjedrem et al., 2012). However, the conditions “for rapid domestication and performance improvement of specialized aquaculture stocks through modern selection programs” exist today as “an increasing number of studies show considerable genetic variation and significant heritability for a wide range of performance traits in aquaculture species” (Olesen et al., 2015). With the foundation laid, demand is increasing—between 2010 and 2030, carp and tilapia production is expected to grow 65 and 100 percent respectively (Kobayakshi et al., 2015)—farmed fish will rapidly be genetically “improved” via selective breeding.

Rapid domestication and ‘improvement programs’ reduce genetic variability and thus increase the susceptibility to disease—a clear welfare issue. The goals of these programs, regardless of the species of animal bred for food, should be redefined to include welfare

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6 The Sustaining Ethical Aquaculture Trade, a project designed to provide the necessary evidence to support seafood trade, funded this study.

7 Fish domestication probably dates to early pond culture in Asia around 2,000 BC, but at that time fish were not being put through selective genetic breeding programs to improve productivity and resource efficiency (Olesen et al., 2015). Fish also have a much longer history of domestication for ornamentation, especially in Asia (Balon, 2004).
considerations (Oltenacu & Algiers, 2005). Producers also need to “adequately balance the demand for improving rapidly fish production performances and the conservation of sufficient genetic variability and capacity of fish to adapt to [a] diverse environment, particularly in the current context of climate change” (Teletchae, 2016).

**Our changing climate**

Climate change has fundamentally altered the way in which conversations about agriculture can occur. Aquaculture will likely be affected by climate related changes in air and water temperatures; changes in sea surface temperatures; changes in other oceanographic variables like currents and wave action; sea level rise; and increased frequency of extreme weather events. These disruptions “will in turn create physiological (growth, development, reproduction, disease), ecological (organic and inorganic cycles, predation, ecosystem services) and operational (species selection, site selection, sea cage technology etc.) changes” (Handisyde et al., 2006).

China’s aquaculture sector is one of the most vulnerable worldwide in terms of its exposure, sensitivity, and adaptive capacity for a changing climate (Handisyde et al., 2006). All of China’s aquatic environments—freshwater, brackish water, and marine water—are highly vulnerable. Such vulnerability is not only an environmental concern, of course, but also a welfare concern: aquaculture systems at lower latitudes, like in China, “suffer higher cumulative mortality and faster outbreak progression, which in turn may be exacerbated by climate change, leading to conditions that select for more virulent pathogens” (Leung & Bates, 2013).

It is important to note that Chinese aquaculture will not only be affected by, but also contribute to, climate change. One meta-analysis of 156 primary, peer-reviewed research articles examined the impacts aquaculture has on human health. Seventy-five percent of the research was focused on Asia, and the meta-analysis found that “most criticism has been directed toward conflict over shared resources and damage to common environments, for example, decline in access to wild aquatic food sources or pollution of fresh water, attributed to aquaculture activities” (Burns et al., 2014, p. 235).

For example, the pollution from finfish aquaculture in China has contributed to the poor state of coral reefs (Hughes et al., 2012); reefs which play a vital role in the sequestration of carbon. Tilman and Clark (2014) examined 555 food production systems to develop a meta-analysis of the lifecycle GHG emissions for 22 food types. They found that the lifecycle GHG footprint of aquaculture systems to range higher than poultry and pork, and in some cases (e.g. per kilocalorie) rival that of ruminant meat (Figure 4).
As our climate continues to change, partially driven by aquaculture itself, Chinese aquaculture and the individual fish who are farmed will be susceptible to direct and indirect disruptions. This poses not only an ecological and food security concern, but also a welfare concern as water conditions deteriorate, disease outbreaks accelerate, and farmed fish are subjected to hostile conditions.

**Focus on China**

Given the massive scope and the relative nascence of the aquaculture industry, there is great urgency to focus on these emerging trends in the world’s single largest farmed fish producing country. As seafood consumption increases, as our oceans are emptied of their fish, and as consumer move away from heavy red meat consumption toward aquatic protein center of plate, Chinese aquaculture practices need to be better understood.

A major challenge when it comes to focusing on Chinese aquaculture: the data is often unreliable. During the 1990s, many suggested that China overestimated its production totals (Delgado et al., 2003). Aquaculture production data is plagued by inaccuracies both in terms of quantities and species. For example, ~300,000 tons of marine fish “nei” (not elsewhere included, or otherwise unidentified species) are farmed in China annually, representing 31% of China’s marine capture, more than any individual species caught from its ocean’s fisheries (Cao et al., 2015). The FAO warns: “the massive scale of China’s aquaculture production challenges statistical collection and there are uncertainties regarding the quantities

![Figure 4](source: Tilman & Clark., 2014, page 519, figure 1).
reported” (FAO, 2012, p. 66, footnote 8). The “nonspecific and often erroneous reporting of fish production and trade makes it especially difficult to assess the impact of China’s aquaculture and aquafeed use on ocean fisheries,” as well as the impact on fish themselves (Cao et al., 2015).

These challenges are difficult, but not insurmountable. For all who care about sustainability, animal welfare, and food systems, Chinese aquaculture needs to be better monitored, understood, and nudged toward a brighter future. There is great urgency for more critical analyses of Chinese aquaculture, as small changes made today may have large impacts on the future—especially if we want aquaculture to avoid some of the problems currently plaguing land animal agriculture.

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8 We should be equally suspicious of consumption data. Many local studies on the ground in China find per capita fish consumption to be 20-35% higher than official statistics (Chiu et al., 2013).
References


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