Animal (2015), **9:6**, pp 917–918 © The Animal Consortium 2015
doi:10.1017/S1751731115000312

Opinion paper: prospects for the fed-aquaculture sector

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First published online 2 March 2015

Since the 1970s, global demand for fish has kept increasing, particularly in developing countries where population and income growth constitute the main drivers of the rise in world fish consumption. Although output from capture fisheries stagnates, total production of fish continues to rise, thanks to aquaculture. In 2010, aquaculture contributed up to 47% of world food fish production against 9% in 1980. The optimistic view is that aquaculture is going to replace – at least partially – open sea fishing, helping to make fisheries sustainable and providing food security to many developing countries.

However, there are concerns that the ecological and socio-economic impacts of aquaculture jeopardize its own sustainability. In particular, open water aquaculture is a polluting industry, that spills effluents (feeds including fertilizers, feces or chemicals) into the wild. Besides, aquaculture increasingly faces problems of space and feed scarcity. The favored locations for farms are coastal areas, where the likelihood of interfering with other human activities is high (fishing, mining, tourism, etc.).

Fish feed is probably the most controversial aspect of the aquaculture production process. Aquaculture relies on fish protein for the feeding of an important share of its production. In 2008, fed-aquaculture contributed to 81.2% of global farmed fish and crustacean production (Food and Agriculture Organization, 2012). Fish meal and fish oil are key ingredients in aquaculture feed. They are made from small oily fish belonging to low-trophic levels (LTL) for about 80% and waste from processed fish for 20%. The FIFO (fish in–fish out) ratio gives the number of tons of wild fish used to produce 1 ton of farmed fish. The overall FIFO ratio was estimated to be close to 0.7 in 2006. At the carnivorous species-group level the FIFO ratio varies quite a lot between surveys, but is clearly >1. For instance, Tacon and Metian (2008) and Naylor *et al.* (2009) on the one hand, and the International Fishmeal and Fish Oil Organization on the other reported a salmon FIFO ratio of 4.9 and 2.2, respectively. The expansion of aquaculture urges to find substitutes to fish meal and fish oil. Some plant and terrestrial animal by-product nutrients are sources of high-quality proteins, but do not present all the properties allowing to maintain the flesh quality of carnivorous species.

In our paper 'Is aquaculture really an option?' (Regnier and Schubert, 2013), we develop a theoretical framework to investigate the impact of the introduction of aquaculture on fish consumption, consumer utility and wild fish stocks, taking into account the sector's dependence on feed fish and consumer preferences.

The theoretical model (see Figure 1) consists of two wild fish stocks in open access and a competitive aquaculture sector. Although the general trend of tightening regulations goes against the assumption of open access, resource management schemes are far from being implemented or efficient worldwide, and this assumption seems reasonable as a benchmark. The wild species 1 is harvested for direct human consumption, whereas the other one (species 3) is used to feed farmed fish. Biological interactions of the predator–prey type take place between the two wild species: the withdrawal of the prey species 3 affects the abundance of the predator species 1, which is higher in the food chain. Consumers may choose to consume wild or farmed fish, which are assumed to be strong substitutes, according to their preferences. Finally, market interactions refer to the competition between farmed and wild fish products on the fish counter, and the resulting prices of both products.

We find that the long-run impacts of the aquaculture entry are conditional on the degree of dependence of the wild edible species on the feed fish stock, and on the level of consumer spending on fish. When biological interactions are moderate and consumer spending remains below a certain threshold, the introduction of aquaculture is of benefit to consumers, whose utility increases. By providing an alternative source of food fish, aquaculture makes the price of the wild product decrease. Fishing effort decreases, allowing the edible stock to recover despite the fact that aquaculture exploits the prey species as an input.

In contrast, when biological interactions are high, the introduction of aquaculture leads to a decline in the two wild fish stocks, a decrease in wild edible fish supply and an increase in its price. At high levels of consumer spending, it

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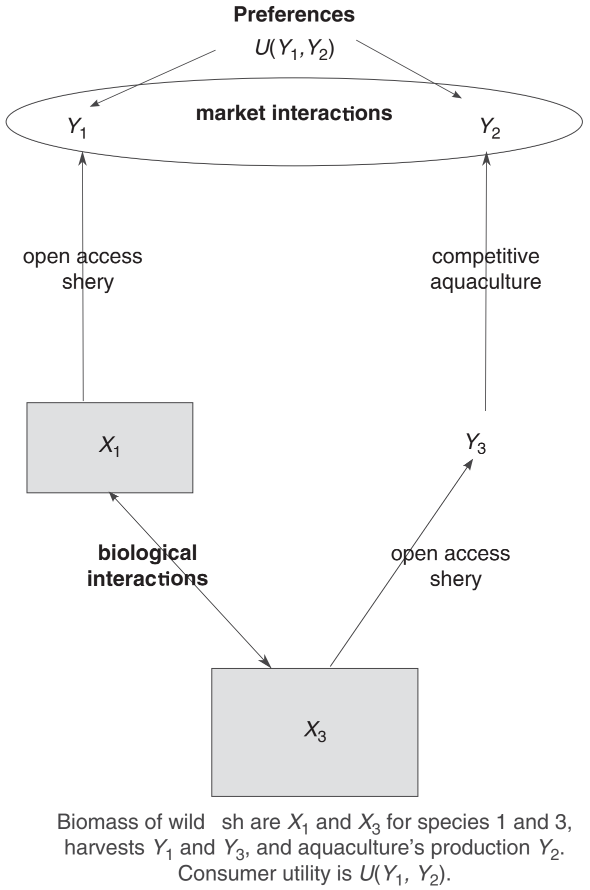

Figure 1 Sketch of the model.

actually provokes the collapse of the wild edible fishery. Indeed, the competition between the predator species and the aquaculture sector for feed fish becomes too strong as food fish demand rises. The net effect of farming on total fish consumption and utility is ambiguous. We show through numerical simulations that the introduction of aquaculture may be harmful to consumers, in spite of the fact that more options are offered to them, because open access fisheries are not exploited optimally.

The outcomes of our analysis are conditional on the open access assumption, on how consumers perceive wild *v.* farmed products, and on the relative efficiency of these two processes in producing fish. In our model, preference and technological parameters are given. As an extension, we investigate how carnivorous species-biased consumer preferences affect our conclusions. Our assumption is that the more carnivorous the farmed species is the more consumers like it. The breeding of highly carnivorous species results in a high demand for feeds. Hence, the more carnivorous the farmed species is the higher the FIFO characterizing its production technology, that is, the more inefficient the aquaculture's technology. Thereby, as the efficiency of the aquaculture sector improves, consumers tend to like farmed fish less. The improvement in the aquaculture's technology can be interpreted as a change in feeding formulas, resulting in a modification of flesh properties that consumers penalize. It can also be interpreted as a genetic modification that enhances growth despite a low-protein intake, the counterpart being that the nutritive properties of the flesh are not conserved. Indeed, consumers tend to be cautious about the potential consequences of these changes. Thus, the beneficial impact of aquaculture on the wild edible stock and consumer utility may be mitigated.

A potential answer to the constrained supply of aquaculture feeds is to split the market of carnivorous species into a cheap market fed with reduced fish oil and an expensive one fed with real n-3 fish oil. Differentiating supply through two lines of quality could better match consumers' willingness to pay for food fish. Another possible option is to direct consumer preferences toward less carnivorous species by means of marketing strategies or educative campaigns. Of course, finding a perfect substitute to fish meal and fish oil remains a first choice option.

From a food security perspective, as one face of the aquaculture industry consists in taking quantities of fish from the sea to produce lower quantities of fish flesh, one may legitimately question: why not supply LTL species for direct human consumption? The explanation seems to be region specific and relates to technological, economic and cultural factors (Hasan and Halwart, 2009).

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https://doi.org/10.1017/S1751731115000312 Published online by Cambridge University Press