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Review Article

Environmental health impacts of feeding crops to farmed fish

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ABSTRACT

Half of the seafood consumed globally now comes from aquaculture, or farmed seafood. Aquaculture therefore plays an increasingly important role in the global food system, the environment, and human health. Traditionally, aquaculture feed has contained high levels of wild fish, which is unsustainable for ocean ecosystems as demand grows. The aquaculture industry is shifting to crop-based feed ingredients, such as soy, to replace wild fish as a feed source and allow for continued industry growth. This shift fundamentally links seafood production to terrestrial agriculture, and multidisciplinary research is needed to understand the ecological and environmental health implications. We provide basic estimates of the agricultural resource use associated with producing the top five crops used in commercial aquaculture feed. Aquaculture's environmental footprint may now include nutrient and pesticide runoff from industrial crop production, and depending on where and how feed crops are produced, could be indirectly linked to associated negative health outcomes. We summarize key environmental health research on health effects associated with exposure to air, water, and soil contaminated by industrial crop production. Our review also finds that changes in the nutritional content of farmed seafood products due to altered feed composition could impact human nutrition. Based on our literature reviews and estimates of resource use, we present a conceptual framework describing the potential links between increasing use of crop-based ingredients in aquaculture and human health. Additional data and geographic sourcing information for crop-based ingredients are needed to fully assess the environmental health implications of this trend. This is especially critical in the context of a food system that is using both aquatic and terrestrial resources at unsustainable rates.

Contents

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1. Introduction

The global food system faces significant stressors in population growth, limited land and water resources, rising demand for animal products, overreliance on fossil fuels, and a changing climate (Foley et al., 2011, Neff et al., 2011). In addition, seafood production has changed substantially over the last few decades. Half of seafood consumed globally currently comes from aquaculture, or farmed seafood, which is increasing at a faster rate than any other animal production sector (UNFAO, 2014a). In the past, seafood production and consumption primarily raised concerns related to overfishing, habitat destruction, and food safety (Botsford et al., 1997, Rasmussen et al., 2005, Feldhusen, 2000). Now, we also need to consider the implications and externalities of farming half of our seafood.

Aquaculture is a diverse sector. Different species of aquatic animals have different nutritional needs and are raised using widely divergent methods (e.g., raised in ponds, rivers, open water net-pens, or land-based tanks). About two-thirds of farmed aquatic animal production requires feed (UNFAO, 2014a). Some species, like tilapia or grass carp, are herbivorous and can consume 100% vegetarian feed made from crops and other food and agricultural byproducts. Historically, many herbivorous fish were raised in extensive systems, where no feed was administered. However, farmers are intensifying production and using farm-made or commercial feeds, some of which contain fish or animal proteins and fats. Other species, such as Atlantic salmon, rainbow trout, and cod, are carnivorous and have always been fed fish or animal protein and/or lipids as part of their diet. Fishmeal (FM) is a common source of protein in aquaculture feeds, although some farms are replacing FM with animal byproducts such as poultry byproduct meal or vegetable protein such as soybean meal. Fish oil (FO) is commonly used as a fat source, but rendered animal fats and vegetable oils are increasingly used in place of (or in combination with) FO.

Aquaculture feed is made by grinding or mixing plant and animal-based ingredients together. In industrialized settings, the mixture of ingredients is passed through an extruder to create bite-sized feed pellets. In commercial feedmills, these extruded pellets resemble pet food kibble and are dried and stored in containers to increase shelf-life. Commercial feeds are considered a "complete feed" that contains necessary amounts of protein, fats, carbohydrates, vitamins, and trace minerals. Aquaculture animals raised on commercial or farm-made feeds reach harvest weight more quickly than animals raised on forage (i.e., in extensive aquaculture where no feed is administered) (Hasan et al., 2007). Therefore, farmers may be motivated to switch from extensive systems to semi or fully intensive systems due to productivity gains. Farmers are unlikely to shift from extensive systems to intensive systems at once; they often follow iterative steps to increase efficiency such as increased fertilization, aeration, pumping, the use of farm-made feed, and finally purchasing commercial feed. The global trend toward increased production and efficiency has dramatically expanded the use of commercial aquaculture feed.

To calculate total commercial aquaculture feed use globally, Tacon and Metian (2015) multiplied aquaculture production for each species by the percent of each species on commercial feed and the efficiency that fish convert feed into mass (i.e., feed conversion ratio). We have reproduced these data in Fig. 1 for the top five species groups to show the different rates of change for each variable within different sectors. More granular data are difficult to obtain and are needed to explain trends within sectors, such as transitioning from extensive methods to semi-intensive and intensive methods, transitions from farm-made feed to commercial feed, and increasing terrestrial feed use. For each type of aquaculture, it would be useful to know if an increase in terrestrial ingredients was due to expansion in overall production and/or substitution of ingredients, such as replacing FM/FO with terrestrial proteins and oils. The global use of non-commercial aquaculture feeds (i.e., farm-made and direct feeding of low-value fish to farmed fish) is estimated to be between 18 and 36 million metric tons (MMT); importantly, the data used in our review focus on commercial aquaculture feeds because the types and amounts of feed

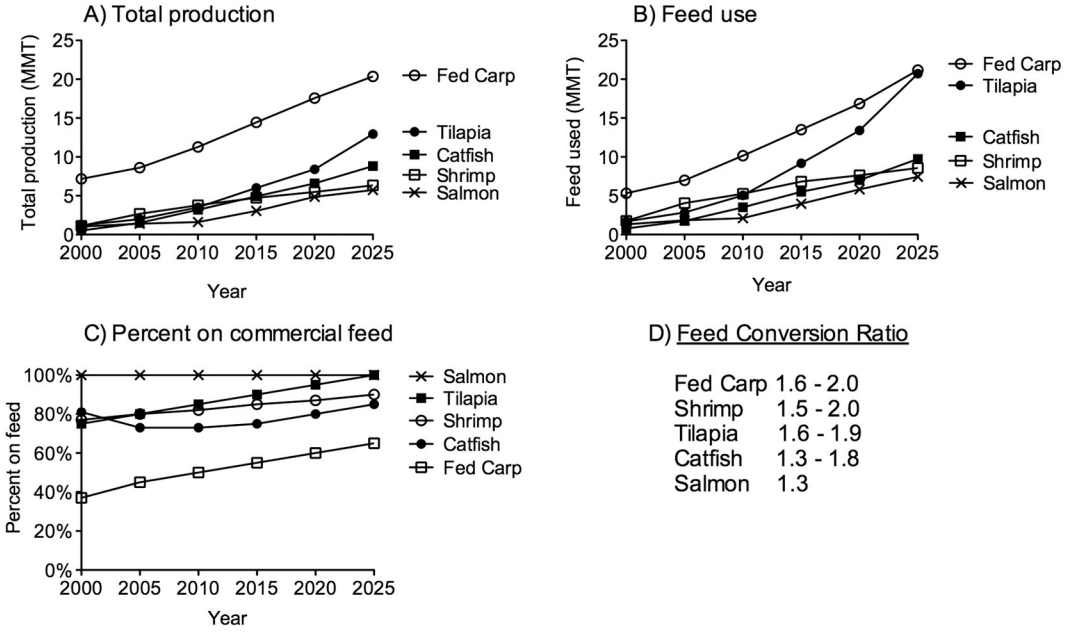

Fig. 1. Estimated A) production, B) commercial feed use, and C) percent commercial feed use 2000–2025 for the top-5 species groups (based on 2015 production data). D) Estimated feed conversion ratios for selected species. Data from Tacon and Metian, 2015.