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Water

Freshwater consumption and pollution in aquafeed production:

an important aspect of sustainable aquaculture growth

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Challenges for the aquaculture sector

Over the years the fishing industry has undergone dramatic changes, as the production of fish and shellfish for human consumption increasingly originates from aquaculture. With the increasing importance of aquaculture in feeding the growing world population the requirement of natural resources for producing aquafeed ingredients is intensifying. There is a growing interest in the potential to replace fish meal and fish oil with terrestrial feed ingredients. It is important to understand both the positive and negative implications of this development with regard to its claim on natural resources. While the use of feed with a large proportion of terrestrial feed may reduce the pressure on fisheries to provide feed for fish in the form of fish meal and fish oil, it may significantly increase the pressure on freshwater resources due to water consumption and pollution in crop production for aquafeed. Furthermore, the competition with feed for humans and livestock, as well as with plant material for biofuels is aggravated.

Using the water footprint as indicator to identify the relationship between commercial aquaculture production and freshwater appropriation

The commercial feed-related water consumption and pollution of fish and crustacean production in aquaculture is estimated here using the water footprint (WF) as indicator. The water footprint is a measure of humanity's appropriation of freshwater in volumes of water consumed and/or polluted. The water footprint is composed of three colors: green (rainwater consumption), blue (surface and groundwater consumption) and gray (water to assimilate pollutants) (Hoekstra et al., 2011).

For the water footprint calculations data on aquafeed production, the feed conversion ratios for the major cultivated species groups and the percentage of those groups that is cultured using commercial feed given by Tacon et al. (2011) for the year 2008 were utilized. Global average data of the green, blue and gray water footprint of feed ingredients were

selected for the current study due to a lack of detailed knowledge regarding the origin of feed ingredients. Further information regarding underlying data and calculation details can be found in Pahlow et al. (2015).

The commercial feed-related water footprint

The total aquaculture production based on commercially manufactured feeds was 17.9 million tonnes in 2008 and the total commercial aquafeed production was 29.7 million tonnes (Tacon et al., 2011; Ramakrishna et al., 2013). The share of global production of commercial aquaculture feeds by major species grouping is shown in Figure 1. In order to determine the water footprint of feed, the feed composition for 39 major species or species groups, covering all species groups shown in Figure 1, have been compiled from the literature. Note that

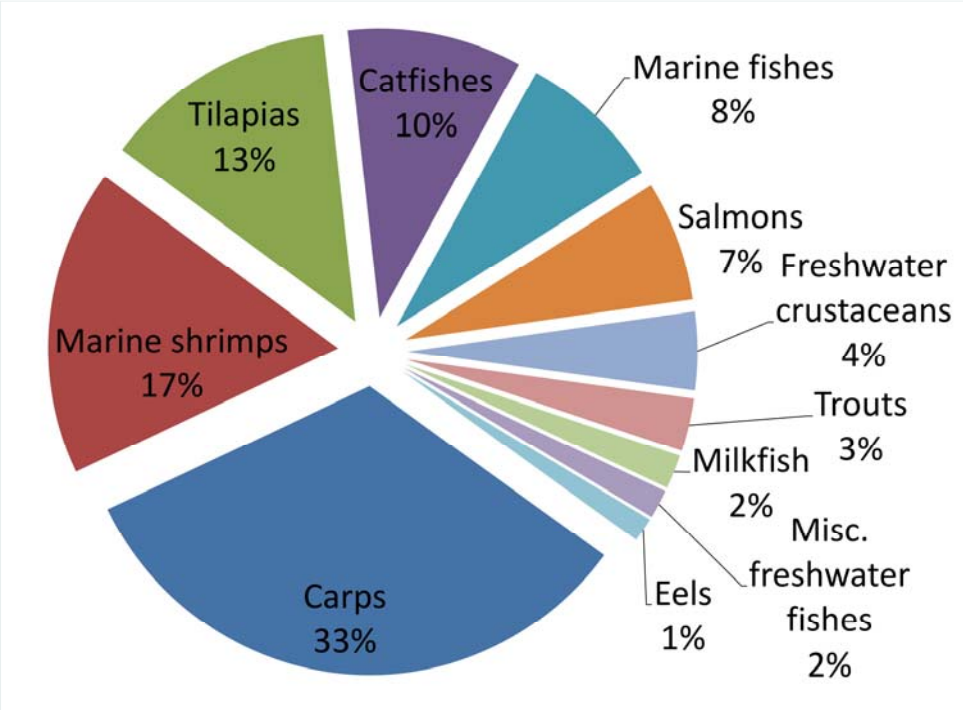

Figure 1. Share of global production of commercial aquaculture feeds of 29.7 million tonnes by major species grouping for the year 2008 (own elaboration based on Tacon et al., 2011 and Ramakrishna et al., 2013).

soybean is the source of plant protein most often used in compound aquafeeds and the most prominent protein ingredient substitute for fish meal in aquaculture feeds (Tacon et al., 2011). For 2008 it was estimated that the aquaculture

sector used 6.8 million tonnes of soybean meal, which was 25.1% of total compound aquafeed. Of that, China was using about 6 million tonnes of soybean meal within compound aquafeed (Tacon et al., 2011).

The water footprint per tonne of cultured fish and crustaceans related to the production of commercial feed for the year 2008 is shown in Figure 2 for the major farmed species investigated here, which account for 88% of total fed production. From that the green, blue and grey production-weighted average feed water footprints of fish and crustaceans fed commercial aquafeed are estimated at 1,623 m^3/t, 177 m^3/t and 166 m^3/t, respectively.

Considering the total production volume it was found that globally the top five contributors to the total commercial feed water footprint are Nile tilapia, Grass carp, Whiteleg shrimp, Common carp and Atlantic salmon, which together accounted for a water footprint of 18.2 km^3 of the estimated total 31 - 35 km^3 in 2008.

Influence of potential variations in feed formulations

Next to the general increase of plant feed ingredient usage due to increased production, replacement of fish meal and fish oil with plant-based ingredients is a highly relevant development and it is important to study this potential shift in aquaculture nutrition provision from a water resources point of view. The water footprint analysis was carried out with alternative research diets taken from the literature for piscivorous rainbow trout, carnivorous Atlantic salmon, carnivorous Atlantic cod, carnivorous European seabass and carnivorous gilthead seabream. The resulting green, blue and gray water footprint values are shown in Figure 3 and it becomes clear that the replacement of fish meal and fish oil with terrestrial feed ingredients in these research diets may further increase pressure on freshwater resources.

Implications for sustainable aquaculture growth

Each fish and crustacean has certain needs in terms of protein, fat, carbohydrates, vitamins, minerals, among others. The question is how those needs can be met in a sustainable way, thereby also considering the pressure on freshwater resources. While the selection of species is not exhaustive in the present study, the result is universal: replacing aquafeed ingredients that stem from e.g. pelagic marine fishes, that do not depend on external feed, with terrestrial feed ingredients that have a related water consumption and pollution in the production process, must lead to an increasing water footprint of the feed. Therefore it is crucial to select feed ingredients that can be sustainably produced and grow with the sector.

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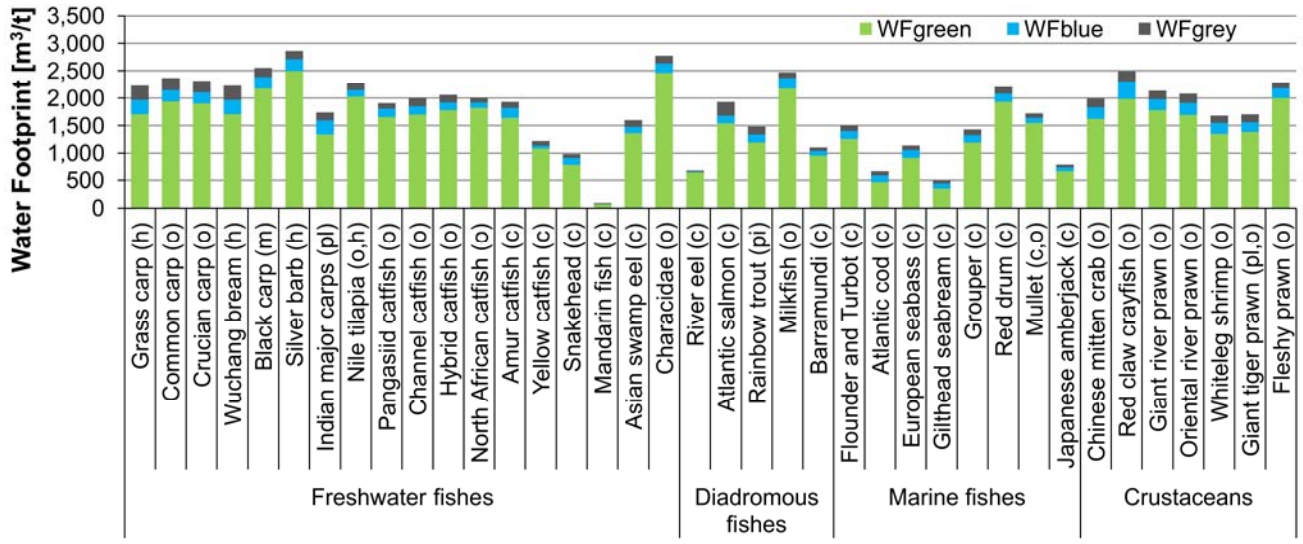

Figure 2. Feed-related green, blue and gray feed water footprint per tonne of fish and crustacean for the species investigated. The dietary category for each species is also indicated: (c) carnivorous, (h) herbivorous, (pl) planktivorous, (m) molluscivorous, (pi) piscivorous and (o) omnivorous. If more than one category is shown then the species falls under different categories in different life stages.

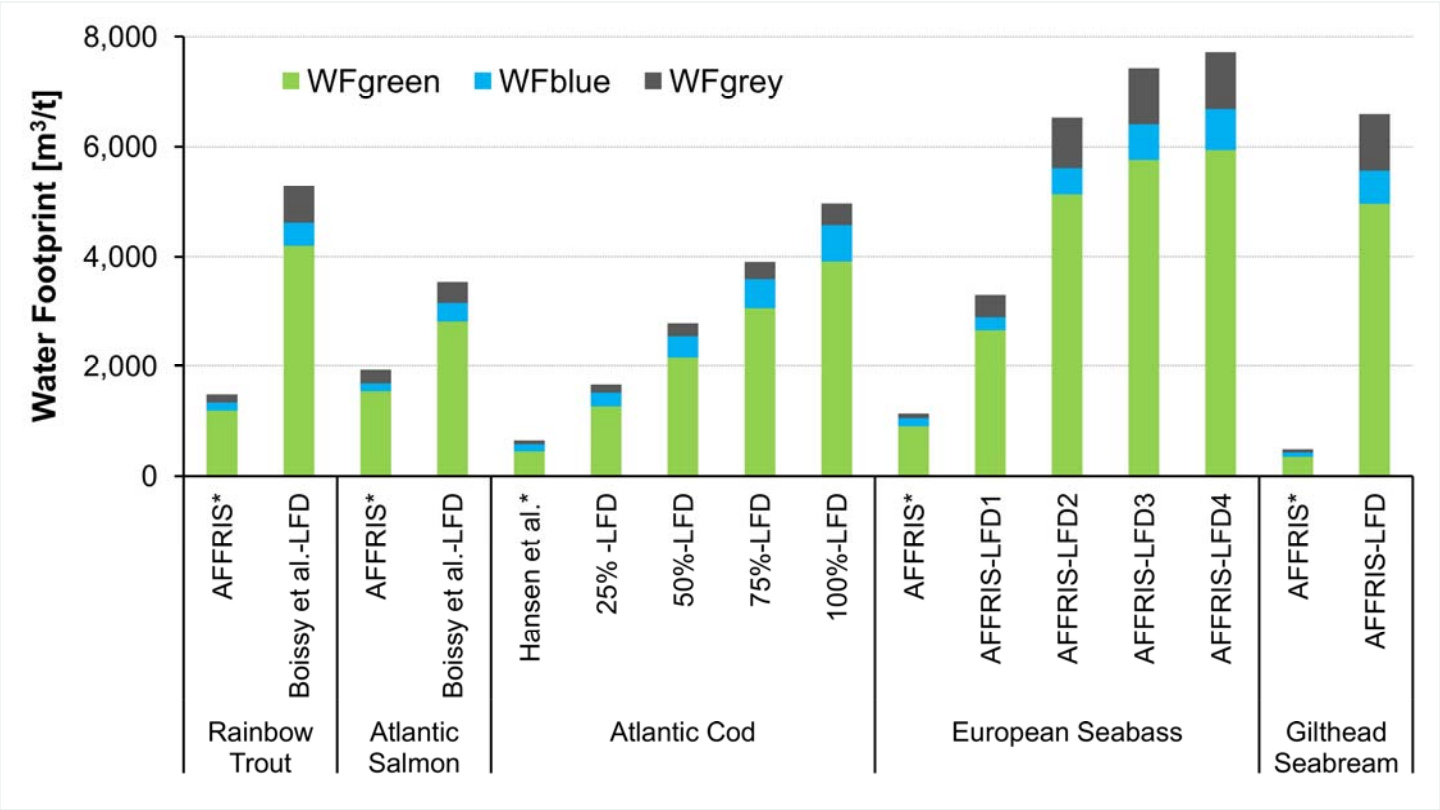

Figure 3. Resulting water footprint values due to alternative research diets from the literature. The star * indicates the standard diet used in this study.

Tacon et al. (2011) project that production and usage of commercial aquaculture feed will increase to about 71 million tonnes in 2020, which will be accompanied by an increase in the related water footprint. Furthermore, global production of farm-made aquafeeds, which was estimated to be between 18.7 and 30.7 million tonnes in 2006, must be included in future studies (Tacon et al., 2011).

Efforts should focus on further improvements in feed formulation techniques and on feed ration development on the basis of individual digestible nutrient levels to ascertain growth and health of the individual species, rather than on crude gross nutrient levels, and at the same time aim to minimize the environmental and ecosystem impact of feeds and feeding regimes, thereby including pressure on freshwater resources.

More information

This article is based on the open-access publication:

Pahlow, M., P.R. van Oel, M.M. Mekonnen and A.Y. Hoekstra (2015) Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production, Science of the Total Environment, 536: 847–857.

Available here.

All references can be found therein. For inquiries, please contact the author, Dr. Markus Pahlow:
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