**Sustainability considerations for replacing forage fish in future aquaculture feeds**

Richard S. Cottrell, Julia L. Blanchard, Benjamin S. Halpern, Kirsty L. Nash, Halley E. Froelich

**Methods**

***Meta-analysis of environmental footprints of alternative feeds fed to farmed aquatic species and their suitability for fishmeal replacement***

* Search of Google Scholar, Scopus and Web of Science databases for Life Cycle Analyses (LCA) of a range of insect, algae, bacteria and yeast products used as a replacement for fishmeal in aquaculture feed.
* We compliment this meta-analysis with studies detailing the effects of insect, algae, bacteria, and yeast-based alternative feeds on feed conversion ratios of farmed finfish or crustacean. We limit this meta-analysis to studies of species grown for the sole purpose of human food production.
* We limit inclusion to LCA studies that address the life cycle of a product from farm-gate and growth-effect studies that specifically replace (rather than add to) fishmeal and/or fish oil with an alternative as a protein or lipid source respectively.
* Initial search terms included “Insects OR algae OR yeast OR bacteria” AND “life cycle analysis” (for LCA studies) or “fishmeal AND replacement” (for study of feed conversion ratios). Secondary searches replaced terms for insects or algae etc. with individual taxa names identified within the first search (e.g. Black Soldier Fly or *Chlorella etc*). We review the first 100 articles returned when sorted by relevance.

*Things to include in meta-analysis data (not already in there):*

* Life stage of target species
* Change in crop-based ingredients with use of alternatives – break this down to individual crops? soy and others? Or just total crops?
* Proportion of feed that is fishmeal?
* Total proportional (?) contribution of algae in feed at each replacement level?

*Caveats:*

* Very few studies use 1:1 replacement of fishmeal with alternative feeds as replacement of fishmeal/oil may co-occur with greater inclusion of other products to obtain the correct nutritional standards for the animal. Therefore, the replacement levels detailed in our analysis imply the proportional fishmeal and oil reduction achieved with the incorporation of alternative sources such as insects or algae.
* Replacement values account for any increase in fish oil that occurs with a loss of fishmeal and vice versa. As we assume forage fisheries provide both fishmeal and oil, the replacement accounts for total forage fish ingredients used.