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## Development of an approach to assess overfishing in Europe based on the Ecological Scarcity Method

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### Abstract

**Purpose** One third of the global fish stocks is classified as overfished. Life cycle impact assessment methods for overfishing exist but are not fully implemented and do not allow to compare results of different impact categories. Thus, a new approach based on the ecological scarcity method (ESC) was developed to be applied in life cycle assessment (LCA) and to compare results of overfishing with other categories like climate change and land use.

**Methods** Based on the ESC and the maximum sustainable yield (MSY) concept, an approach was developed to assess overfishing. The region specific approach considering the overall catch in Europe in relation to the European catch within sustainable limits (MSY) and defines the overfishing indicator as the species-specific characterization factor. The introduced approach was applied to the production of three salmon feed: feed 1 with fish oil and fish meal; feed 2 with VERAMARIS® Algal Oil and fish meal; feed 3 with VERAMARIS® Algal Oil and other agricultural ingredients and compared to the impact categories climate change and land use.

**Results and discussion** When comparing the three different feed in the categories climate change, land use and overfishing it was determined, that the category overfishing had the highest impacts for feed 1 and 2, because both feed contain fish meal and/or fish oil. For feed 3, where the omega-3 fatty acids come from algae oil and agricultural products only, the overfishing impact was zero. The impacts in the categories land use and climate change increased only slightly with growing amounts of agricultural products. One of the main reasons for the high overfishing impacts is the defined target of having no overfishing, whereas the targets of the other two categories are formulated less ambitious. This result would therefore change, when other more ambiguous targets are considered, for example for climate change.

**Conclusions** A new approach was developed for the assessment of overfishing in LCA, which allows for the comparison of different impact assessment categories. Its applicability was demonstrated within a case study comparing different fish feed. It was shown, that the use of wild fish in fish feed in Europe leads to high overfishing impacts, whereas the use of algae oil does not significantly increase impacts of land use and climate change.

**Keywords:** overfishing; algae oil; ecological scarcity approach; maximum sustainable yield; weighting

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## Introduction

The fishery and aquaculture sector plays a significant role in the provision of food and nutrients. However, overfishing has been a global issue for several decades, because around one third of the global fish stocks are classified as overfished. Overfishing refers to depletion of stocks due to fishery beyond the maximum sustainable yield (MSY); thus, more fish are caught than needed to be able to regenerate. Impacts of overfishing include biodiversity loss, decrease of ecosystem services as well as reduced availability of fish and therefore social and economic consequences. (Food and Agriculture Organization of the United Nations 2020) Thus, overfishing has been addressed by the SDG 14 (Life below water: conserve and sustainably use the oceans, seas and marine resources for sustainable development) with the goal to end overfishing by 2020 (United Nations 2016). This goal was also translated into many regional goals, e.g. for Europe, where overfishing is to be phased out by 2030 (European Commission 2020).

One strategy to reduce the pressure on overfishing is the use of aquaculture. However, in all aquacultural systems currently fish meal and oil produced from wild fish is used as feed. In 2018 around 22 million tonnes of fish were used to produce fishmeal and fish oil. Thus, adapting aquaculture fish farms by reducing fish meal and oil can be a significant contribution to tackle overfishing. Agricultural products like crops have been a preferred substitute for fishmeal. Their production can lead for example to impacts regarding climate change and land use. As agricultural products do not have the necessary nutrients to replace fish oil, algae oil has been the favored substitute for fish oil, but can just recently be produced in the necessary amounts due to technological advancements in its production (e.g. Shah et al. (2018)).

Thus, one goal of the paper is, to analyze the environmental impacts of the categories overfishing, climate change and land use by replacing fish oil and meal with agricultural products and algae oil.

However, so far no adequate impact assessment methods for life cycle assessment (LCA) exist to measure overfishing. Most methods are based on the primary production, which is an indicator accounting for productivity but not scarcity and therefore does not adequately reflect overfishing (e.g. Emanuelsson et al. (2014); Cashion et al. (2016); Stucki et al. (2018)). Thus, a new approach had to be developed which allows for the assessment of overfishing from a scarcity point of view. Further, this approach had to be able to compare different impact assessment results in order to compare diverse food systems despite existing tradeoffs.

The new impact assessment approach was tested in a case study comparing three salmon feed with different omega-3 fatty acids, and protein sources:

- Feed 1 with fish oil and fish meal
- Feed 2 with the VERAMARIS® Algal Oil, and fish meal
- Feed 3 with the VERAMARIS® Algal Oil and other agricultural ingredients.

## Material and methods

The introduced approach is based on the ecological scarcity method (ESC) (Müller-Wenk 1978; Frischknecht and Büsler Knöpfel 2013) and the maximum sustainable yield concept. The MSY concept is the basis for many existing overfishing indicators inside and outside of LCA (e.g. Phillips, Anderson, and Schapire (2006)). The ESC method was originally developed in 1978 to be applied to Switzerland. The method has been continuously updated since then and was further applied to many other countries and regions, e.g. the European Union (Muhl et al. 2019). The ESC sets a current flow (e.g. emission in a region) in relation to a defined target (e.g. allowed emissions) and normalizes the result by the current flow.

The developed approach is a region specific approach, with the following terms (see equation 2):

- Current flow: overall catch in Europe
- Target: European catch still within sustainable limits, which is determined by dividing the overfished catch from the overall catch
- Species specific characterization factor (CF): overfishing indicator based on (Ziegler and Valentinsson 2008; Ziegler et al. 2011)
- Normalization factor: species specific overfishing indicator results for the European catch
- Constant c: mathematical term ( $3,68 \cdot 10^3$ )

$$Ecofactor = CF_i \times \left( \frac{overall\ catch_{Europe}}{(overall\ catch - overfished\ catch)_{Europe}} \right)^2 \times \frac{1}{\sum(CF_i \times catch_i)_{Europe}} \times c \quad (\text{Equation 2})$$

Existing ecofactors for Europe from Muhl et al. (2019) are applied to determine the result for the categories climate change and land use.

### Results and discussion

Figure 1 shows the results (expressed in ecopoints) for the three different feed in the categories climate change, land use and overfishing.

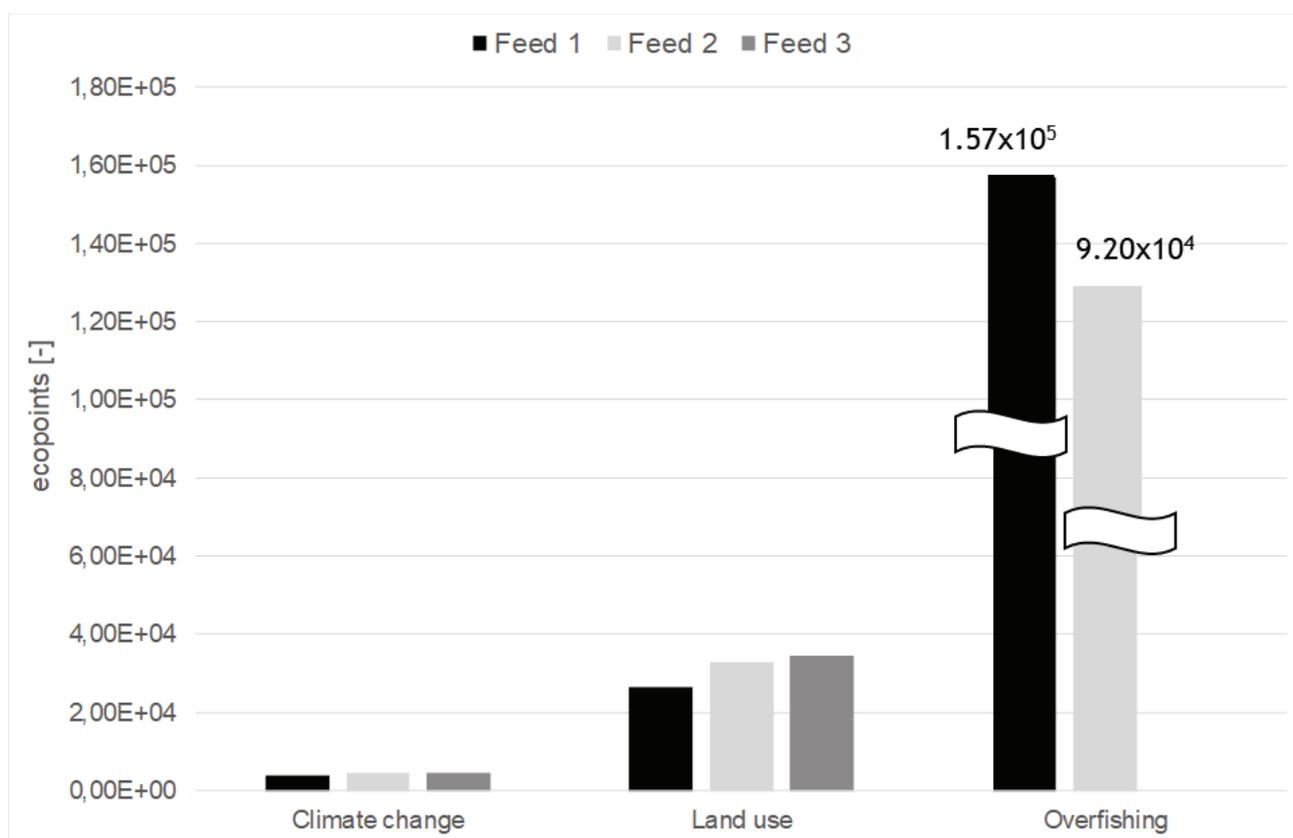


Figure 1: Results of the three different feed for climate change, land use and overfishing

It can be seen that the category overfishing has significantly higher results compared to climate change and land use for feed 1 and feed 2. Both feed contain fish meal and/or fish oil made out of wild fish and therefore contribute to overfishing. For feed 3, where the omega-3 fatty acids come from algae oil and agricultural products replace fish meal, the overfishing impact is zero.

The impacts of the categories land use and climate change are significantly lower compared to the

category overfishing and only slightly increase with growing amounts of agricultural products.

One reason for these results is the applied weighting factor of the category overfishing. Compared to climate change and land use the European target of phasing out overfishing by 2030 is much more precise and strict compared to the goals for the other two categories. Even though goals on European level are formulated, they are less ambitious. Thus, for many fish species used in fish meal and oil this target is reached and often exceeded (many fish species are already overfished or at the boarder of being overfished), the goals are not yet reached for climate change and land use. The overall results however, could change significantly if targets for climate change proposed by e.g. NGOs with net zero would be applied instead of targets by the European Commission.

Currently, 67% of the fish species used for the production of fish meal and oil in Europe are overfished. To determine how a decrease in use of overfishing species would influence the results of the considered product system, the breakeven point of the categories overfishing and land use was determined. Therefore, the share of overfished species used in feed 2 were modified to be at 10%, 20%, 30% and so on. As shown in Figure 2, only around 10% of the fish species need to be overfished for the category overfishing being more significant than land use. This underlines the conclusion that using algae oil instead of fish oil in salmon feed contributes to tackling overfishing.

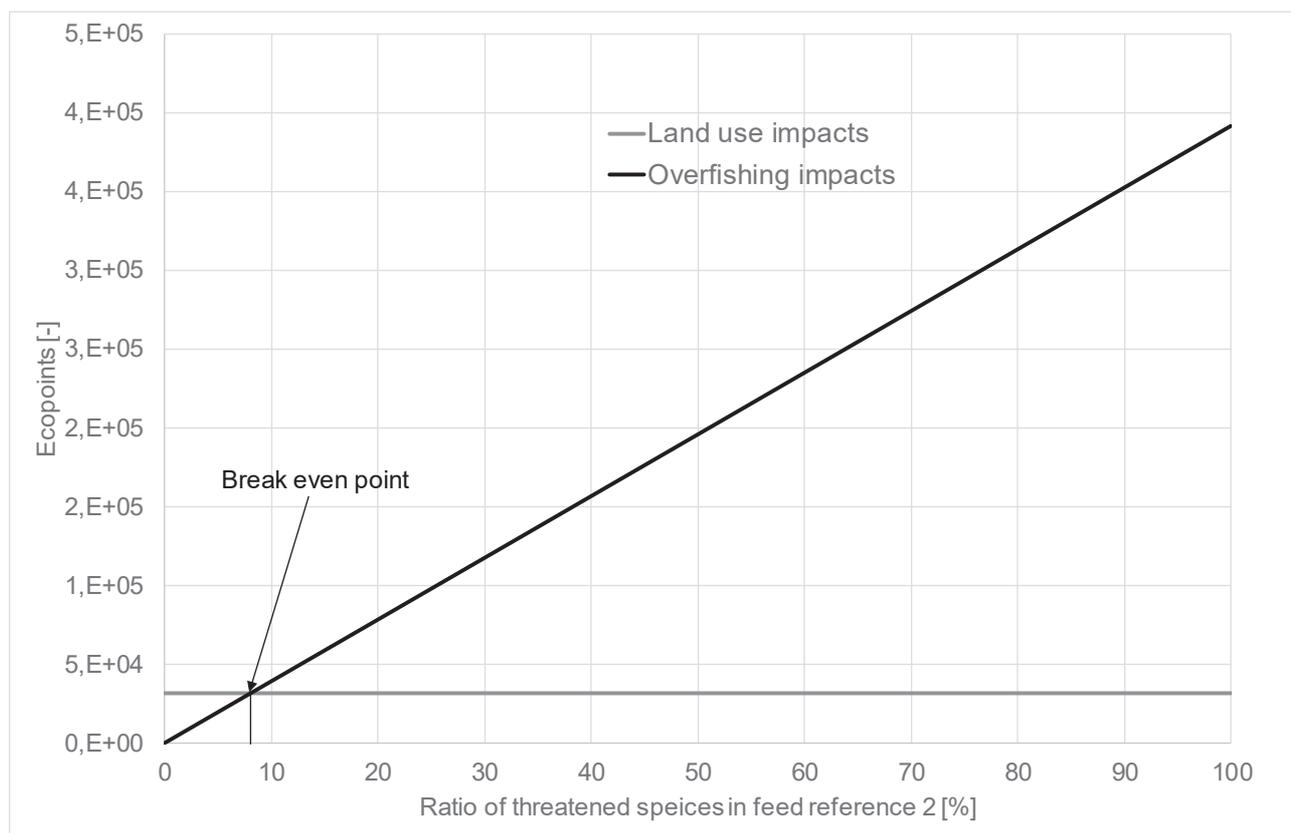


Figure 2: Break-even point of the categories overfishing and land use

The developed approach for overfishing is new and has only be applied for this one case study presented here. To make sure that it provides reliable results, it has to be tested on more case studies. Another challenge is the data availability, as data for many species is not regularly collected. For some species like boar fish it has only been collected for the last five years. Further, several environmental conditions can influence the availability of species in the ocean, e.g., El Nino events cause an increase in air and water temperature, which can lead to extinction of e.g. cold-water anchoveta.

## Conclusion

The newly developed approach to account for overfishing was applied in a case study for salmon fish feed. It could be shown that the approach is applicable and leads to adequate results. It allows for a comparison of different impact assessment methods and can therefore assess the tradeoffs when replacing fish meal and oil with agricultural products and algae oil. When such a replacement takes place, the overfishing impacts can be reduced to a higher extent than the increasing climate change and land use impacts.

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