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1. Introduction

Fishing is older than agriculture and for thousands of years, catches did not really modify the marine communities, but the recent intensification from the last century changes the situation: from a human point of view, fish is now a biotic resource provided by oceans to manage and to exploit. Fisheries modified all the marine ecosystems. Life Cycle Assessment (LCA) successes to quantify the land use by human activities and its consequences on the environment (the ecosystem quality area of protection (AoP)) [1]. On the other hand, the impact of sea use on ecosystems appears poorly assessed by LCA community.

To our knowledge, there is no approach assessing ecosystem impact of fisheries (the withdrawal of fish) which would be compliant with the current guideline. This lack of indicators is highlighted for comparison between sea- and agricultural-based products: the impacts are not expressed in the same unit and are not comparable. With the current LCIA possibilities, the causal effect on ecosystem quality of fishing cannot be represented, that means its impact equals zero. The aim of the present work is to solve this situation proposing operational CFs for global fisheries. They are consistent with international guidelines for land use [1] converting inventoried mass into an ecosystem quality unit and are an extension of a recent work on biotic resource depletion for fish [2,3].

2. Materials and methods

The impacts leading to ecosystem quality are often addressed with CF = FF ×EF. For a given intervention, the characterization factor (CF) is the product of the fate factor (FF) with the effect factor (EF). FF allows the representation of the time period during which the effect occurs and the second gives the associated effect.

In a recent work, we defined CFs for biotic resources (natural resource AoP) based on population dynamic model and marginal approach[2]. This approach is based on the depleted stock fraction (*DSF*), which varies from 0 for a plentiful stock to 1 for an exhausted one. For a biotic resource, we have an analogy between the depletion of the resource and the biodiversity impact. In this way, fisheries leads to a loss of biodiversity, because of the withdrawal of part of the living biomass. The *DSF* represents the disappeared fraction of the stock (the given species in its habitat) and the unit is therefore species lost/kg and can be used as EF.

Most impacts leading to ecosystem quality (e.g. ecotoxicity, acidification, eutrophication, etc.) result from substance emissions. In this context the fate factor represents the persistence of the involved substance in the media.[4] It is usually expressed in years or days. Fate factor is driven by compartment transfers and substance degradation. For a given compartment, it can be assimilated to the inverse of the sum of the removal rates [4] or to a residence time[5]. The fate factor for an impact on the ecosystem of fisheries is reversed since it results from a resource withdrawal, but the principle remains the same. In USEtox®, fate factors are determined as the inverses of exchange- and removal-rate constants. By analogy, we defined the fate factor as the inverse of the growth rate of the fish stock.

The CFs are defined as follows:

$$\mathrm{CF} = \mathrm{FF} \times \mathrm{EF} = \frac{1}{r} \times \frac{C}{rB^2} = \frac{C}{(rB)^2}$$

where B is the fish biomass (ton), C the annual catch (ton.year^{-1}), r the growth rate (year^{-1}). The conversion from species.year /kg to regional PDF.year/kg can be easily done with the division by the number of species of marine region. We have calculated CFs for almost 5000 fish stocks identified by FAO, using both marginal and average approaches and considering vulnerability scores to convert regional PDF to global PDF.

3. Results and discussion

The 5000 regional CFs are spread over ten orders of magnitude but with the interquartile over less than two. The global CFs vary over 13 orders of magnitude but here again the interquartile is much more compact with two orders of magnitude.

As illustration, four fisheries are presented and compared to livestock production. The ecoinvent database is used (v3.5 “at point of substitution” system model implemented in Simapro® v9 software). The worst system, when assessed in species.years and the ReCiPe Hierarchist method (Figure 1) is the beef (world average process) as described in ecoinvent database. The fisheries display contrasted results. The impact on ecosystem quality of Alaska pollock from Northwest Pacific is very low (2% of beef impact), whereas the Atlantic bluefin tuna (75%) shows a result between the pork and the beef systems. Yellowfin tuna and seabass show intermediate results. Except Alaska pollock significantly lower, the three other marine systems show result in the same order of magnitude than the terrestrial system. Interestingly, according to ecoinvent data, the ReCiPe impact associated with a tuna fishery (bluefin and yellowfin tunas) is significantly higher than the impact of a demersal fishery (Alaska pollock and North-East Atlantic seabass). This mainly comes from the diesel burned by the fishing vessel, which is considerably more prominent for tuna fishing. Because of that, yellowfin tuna is almost ten times worse than Alaska pollock, with an impact close to chicken one, whereas both yellowfin tuna and Alaska pollock are low fishery impact. The impact on fish stock is much more visible for seabass. It appears comparable to bluefin tuna impact.

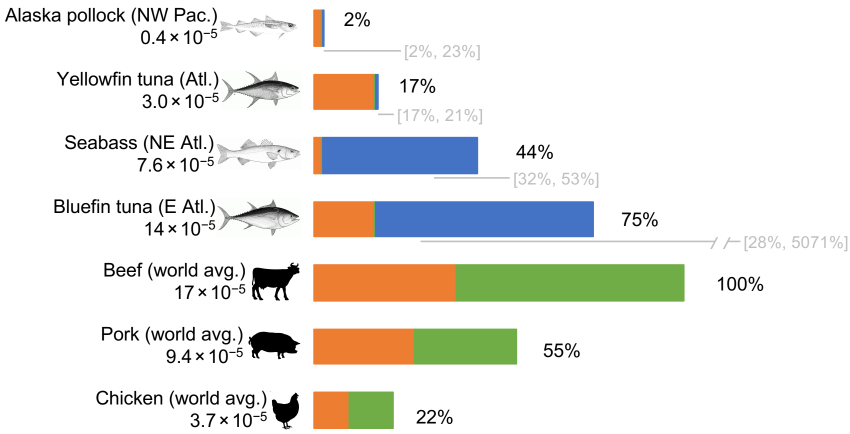

Figure 1: Impact on ecosystems of the four fisheries and the three terrestrial meat production systems. Results are expressed in the percentage of the worst system and impact of each of them are given below the names (in species.year). Orange: sum of all ReCiPe (Herarchist) ecosystem impact except land use. Green: ReCiPe Land use impact. Blue: Fishery impact on fish stocks. Grey line: uncertainty range associated with the fishery impact.

4. Conclusions

The use of the sea by fishing activities leads to a loss of marine biodiversity. The work presented here offers operational CFs dedicated to this, for all global fisheries, in accordance with the LCI guidelines and the ReCiPe method.

5. References

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