Ecosystem Dynamic model for biodiversity impact assessment in LCA: Proof of concept on fisheries in the Adriatic Sea.

Chloe Stanford-Clark, Eléonore Loiseau, Cécile Bulle, Arnaud Hélias

To cite this version:

Chloe Stanford-Clark, Eléonore Loiseau, Cécile Bulle, Arnaud Hélias. Ecosystem Dynamic model for biodiversity impact assessment in LCA: Proof of concept on fisheries in the Adriatic Sea.. 13th International Conference on Life Cycle Assessment of Food 2022 (LCA Foods 2022), Oct 2022, Lima, Peru. hal-04218722

HAL Id: hal-04218722
https://hal.inrae.fr/hal-04218722

Ecosystem Dynamic model for biodiversity impact assessment in LCA: Proof of concept on fisheries in the Adriatic Sea.

Chloe Stanford-Clark[1,2*], Eléonore Loiseau[1,2], Cécile Bulle[3,4], Arnaud Hélias[1,2]

[1]*ITAP, Univ. Montpellier, INRAE, Institut Agro, Montpellier, France*
[2]*Elsa, Research group for Environmental Lifecycle and Sustainability Assessment, Montpellier, France*
[3]*CIRAIG, Department of Strategy and Corporate Social Responsibility, ESG UQAM, Montréal, Canada*
[4]*CIRAIG, Department of Chemical Engineering, Polytechnique Montréal, Montréal, Canada*

Keywords: *Dynamic ecosystem modelling; biodiversity; fisheries; Life Cycle Impact Assessment.*

**Corresponding author.*
E-mail address:chloe.stanford-clark@inrae.fr

Rationale

Global decline in wild capture fisheries is now widely accepted. Principle factors contributing to this decline include pollution, climate change, destructive and unsustainable fishing practices, discard mortality and illegal, unreported and unregulated fishing (FAO, 2020). Over-exploitation of wild capture fish stocks is the most direct threat to the future of global seafood, arising due to global human population growth, increasing demand for fish products, and inequality in fisheries policy and management efforts (IPBES, 2019). Life Cycle Assessment (LCA) methods are a robust way of understanding potential environmental impacts of products and human activities such as fishing, a crucial step to achieving sustainability and resilience in seafood supply required by international Agreements and targets including UN Sustainable Development Goal 14 (SDG14). In Life Cycle Impact Assessment (LCIA) methods, marine impact pathways are relatively under-developed in comparison to terrestrial counterparts. This limitation means these impacts are not currently included in LCA studies nor any subsequent decisions that are informed by these studies. This lag in development however, provides both impetus and opportunity to develop these impact pathways, improving assessments and their contribution to tools and decision making towards more sustainable fisheries.

Objective & Approach

This work introduces a novel LCIA methodology, incorporating ecosystem dynamics into cause-effect modelling and applied to marine ecosystems, to holistically quantify the impact of fishing activities on biodiversity. The approach incorporates the cascade of impacts initiated at ecosystem level including the natural variation within the ecosystem otherwise hidden from impact assessment, to enable a more realistic assessment of the impacts of human activity on ecosystem quality.

Building on the pioneering LCIA approach developed by Hélias *et al* (2018) and Hélias and Bach (2021) quantifying the impact on targeted stocks based on individual species modelling, this approach explores the inclusion of dynamic ecosystem modelling. The assessment is thus elevated from species to ecosystem scale, through consideration of inter-species interactions. The ongoing objective of the work is to define how best to integrate the dynamic representation of biotic ecosystem change into the LCIA framework at both the midpoint and endpoint level until the quantification of damage to the Ecosystem Quality Area of Protection (AoP). Proposals will be made to quantify characterisation factors (CFs) using the recommended metric Potentially Disappeared Fraction (PDF) of species to represent biodiversity loss.

A proof of concept is presented, using fisheries and ecological data from the Adriatic Sea ecosystem

(FAO fishing area 37. 2.1), as the first step towards regionalised, global characterisation of the holistic, ecosystem scale impact of biomass removal by fisheries, using the data that is currently available. The Adriatic Sea is a sub-region of the Mediterranean and Black Sea FAO fishing area, a region currently experiencing disproportionally heavy exploitation levels. It is also well studied from an ecological perspective, making it a suitable choice for a proof of concept in terms of data availability and studies for comparison, as well as being a manageable size in terms of preliminary data collection and modelling groundwork.

Methodology

Ecopath with Ecosim (EWE), a suite of models based on trophic food-web interactions, is widely cited as one of the most robust and commonly implemented ecosystem models. It has been applied at a broad range of scales both in fisheries management and ecological studies and even in conjunction with LCA, to achieve more holistic assessment of systems and supply chains of seafood products (Avadí *et al*, 2014). Whilst the choice of model itself is not a novel fusion with LCA, the aim of this work is to build a generic modelling framework that can be fed with region-specific fishery and biophysical information in order to achieve a globally consistent approach to the endpoint. Whilst previous efforts have provided integration of a range of mid-point indicators for over-fishing, trophic level impacts (Hornborg *et al.*, 2013), potentially lost yield (Emanuelsson *et al.*, 2014) and most recently distance-to-target indicators (Bach *et al.*, 2022), these predominantly relate to impacts on the Resources AoP (Langlois *et al.*, 2014) and are not currently operational.

Using an adaptation of the time dynamic module of EWE (Pauly, Christensen and Walters, 2000), temporal changes in the biomass of species and/or functional groups are simulated in response to fishing pressure and species interactions. This allows the effects of predation and other mediating factors occurring in the marine ecosystem to be integrated. Each year of the simulation is fed by the biomass produced as a result of these interactions during the previous year. Figure 1 emphasises the main phenomena encompassed by the modelling.

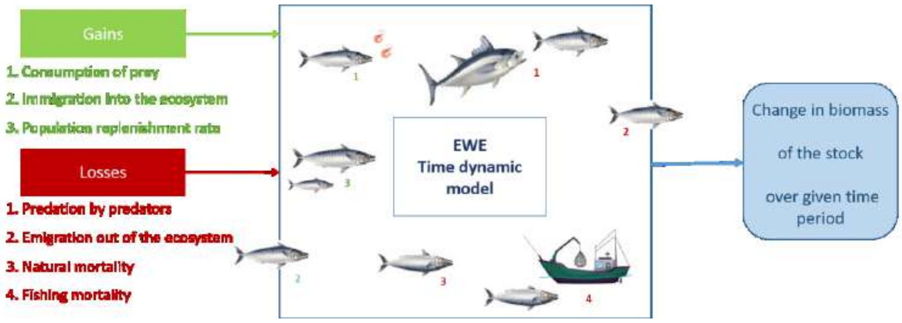

Figure 1. Principles of the dynamic modelling approach

The Adriatic Sea model consists of 188 marine species and 42 Functional Groups reported in FAO catch data for the area, and for which biological data is available online in Fishbase and Sealifebase databases. With this data it is possible to have two approaches, one making use of individual species level detail provided by FAO FishStatJ database of any species included in catch reported by fisheries operating that that area. A second variation, commonly implemented in EWE models, is the use of up to 44 Functional Groups, which categorise marine species based on ecological and physical traits including habitat preferences and size, and an average value is derived for each input parameter.

Dynamic inter-species interactions are simulated through a system of ordinary differential equations. Interactions are introduced as predation pressure on each prey type, based on a version of a generic diet matrix defined by Christensen *et al* (2008) where each species is both predator and prey as defined by column or row, represented as a proportion of the biomass making up the diet of each predator. Foraging arena principles (Ahrens *et al,* 2012) also enable detail to be added on fish behaviours relating to predation effectiveness and predator avoidance, as well as the direct influence of biomass removal by fishing.

Main results & Discussion

The modelling approach allows the characterisation of the ecologically dynamic impact of fishing activity in the Adriatic Sea. Midpoint CFs are developed for fish stocks, as the first step to quantifying the direct and indirect impacts of biomass removal on biodiversity into the LCA framework. A predictive time series of biomass for each species and functional groups will allow the calculation of a range of fisheries relevant indicators to explore the relative state of stocks over time as well as providing a midpoint CF for biotic change. These can be explored for ancillary understanding and comparison of impacts in the ecosystem, as well as the data for calculating damage level CFs.

The key novelty that this approach ultimately aims to provide is the completion of the impact pathway for biomass removal to the endpoint for Ecosystem Quality. The derivation of an endpoint indicator in PDF is a central line of work, to ensure harmonisation in line with UNEP-SETAC GLAM recommendations (Frischknecht and Jolliet, 2016) and has raised some challenges. The calculation of PDF, a metric that is closely linked to land use change impacts where an impact in the ecosystem can be assumed to affect any species occurring there to some extent, is most commonly measured using unspecified species richness changes. As fisheries are both the impact and the impacted medium, with species level data available this presents the possibility to have a more detailed level of assessment through change in abundances within the ecosystem. This is however, a deviation from the typical method of applying PDF. Possibilities to consider are outlined in Figure 2. Options include deriving a fractional PDF that incorporates abundance information over the total ecosystem, or applying a fisheries relevant threshold, to link depletion of abundance to the potential disappearance of the species, similar to the PAF (Potentially Affected Fractions of species) to PDF approach applied to ecotoxicology impacts. In this sense, several options will be discussed to estimate CFs at the endpoint level.

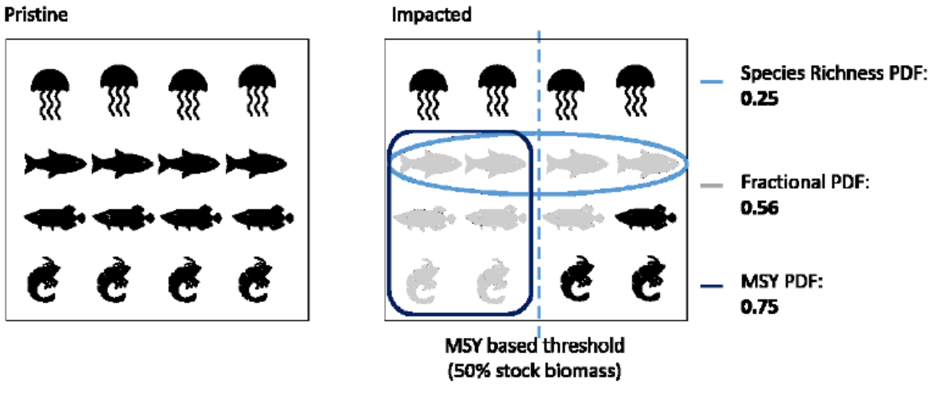

Figure 2. Possibilities to derive endpoint Characterisation Factor consistent with PDF metric.

Another novel element introduced into impact assessment is by this method is how to represent the temporal dynamism of the system and of the impact. This therefore poses several methodological questions, including how to deal with temporality within the static structure of characterisation factors, and how to link the midpoint to the endpoint.

Several methodological challenges and limitations are acknowledged, stemming from a variety of currently unavoidable elements. Ecological modelling is inherently data intensive, and EWE is no exception. When coupled with the ambitious scale of the approach to deliver regionalised modelling with global coverage, data availability and consistency becomes a key challenge, due to differences in reporting quality, formats and regularity between regions. Due to the size of the model, there are instances where data is not available requiring an estimation to be introduced in order to maintain a globally consistent approach, including the use of a generic diet matrix which can be adapted to reflect the constituents of each ecosystem. The requirement of certain input data to be estimated rather than coming from real world data also introduces an additional source of uncertainty. The need to strike a balance describing a system as complex as the ocean with the simplification required by modelling, is then further reduced down to one indicator metric in the LCA framework.

Conclusion

The ability to include a more holistic representation of fishing impacts improves the comprehensiveness of impact assessments relating to the lifecycle of seafood products. This in turn improves the informative capability of LCA as a tool for guiding decision-making and tangible action towards achieving the goals defined by treaties and conservation targets, including SDG14. Application of the approach globally using FAO Major fishing areas for regionalisation represents the next step. This proof of concept presents an approach to improve the accuracy of fisheries LCIA using dynamic ecosystem modelling, thus providing a step towards more realistic, regionalised understanding of impacts to be faced in the future of global seafood supply. This advance, when applied globally can guide the development of more sustainable fisheries policy. Thus facilitating improved stock management in individual ecoregions to a more uniform standard, towards the goal of creating a sustainable industry capable of feeding the world whilst conserving and improving ocean health.

References

Ahrens, R. N. M., Walters, C. J. and Christensen, V. (2012) 'Foraging arena theory', *Fish and Fisheries*, 13(1), pp. 41–59. doi: 10.1111/j.1467-2979.2011.00432.x.

Avadí, A., Fréon, P. and Tam, J. (2014) 'Coupled ecosystem/supply chain modelling of fish products from sea to shelf: The Peruvian anchoveta case', *PLoS ONE*, 9(7). doi: 10.1371/journal.pone.0102057.

Bach, V. *et al.* (2022) 'Assessing overfishing based on the distance-to-target approach', *International Journal of Life Cycle Assessment*, 27(4), pp. 573–586. doi: 10.1007/s11367-022-02042-z.

Emanuelsson, A. *et al.* (2014) 'Accounting for overfishing in life cycle assessment: new impact categories for biotic resource use', *The International Journal of Life Cycle Assessment*, 19(5), pp. 1156–1168. doi: 10.1007/s11367-013-0684-z.

Frischknecht, R. and Jolliet, O. (eds) (2016) *Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1*. Paris: UNEP/SETAC Life Cycle Initiative.

Hélias, A. and Bach, V. (2021) 'A New Impact Pathway towards Ecosystem Quality in Life Cycle Assessment: Characterisation Factors for Fisheries', *Under Review*, pp. 1–32.

Hélias, A., Langlois, J. and Fréon, P. (2018) 'Fisheries in life cycle assessment: Operational factors for biotic resources depletion', *Fish and Fisheries*, 19(6), pp. 951–963. doi: 10.1111/faf.12299.

Hornborg, S. *et al.* (2013) 'Trophic indicators in fisheries: A call for re-evaluation', *Biology Letters*, 9(1). doi: 10.1098/rsbl.2012.1050.

IPBES (2019) *Summary for policymakers of the global assessment report on biodiversity and ecosystem services*, *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Available at: https://zenodo.org/record/3553579#.YfmYTerMI2w.

Langlois, J. *et al.* (2014) 'New methods for impact assessment of biotic-resource depletion in life cycle assessment of fisheries: theory and application', *Journal of Cleaner Production*, 73, pp. 63–71. doi: 10.1016/j.jclepro.2014.01.087.

Pauly, D., Christensen, V. and Walters, C. (2000) 'Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries', *ICES Journal of Marine Science*, 57(3), pp. 697–706. doi: 10.1006/jmsc.2000.0726.