ASSESSMENT OF BIODIVERSITY MEASUREMENT APPROACHES FOR BUSINESSES AND FINANCIAL INSTITUTIONS

EU Business @ Biodiversity Platform

UPDATE REPORT 3

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Cover photo (*Libellula depressa*) by Johan Lammerant

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ANNEX 4: CASE STUDIES

Case study 1: PBF Salmon

Farmed salmon production: what are the main impacts on biodiversity? A generic case study with the Product Biodiversity Footprint

GENERAL INFORMATION

Biodiversity measurement tool	**Product Biodiversity Footprint**
Company	**None - based on literature**
Sector	Seafood
Turnover	-
Date/Period of measurement (year(s))	2018-2019

Business application(s)

BA 4: Comparing options	Assessment of average farmed salmon. This assessment is compared to wild caught salmon

Organisational Focus Area (site, product, supply chain, …)

OFA 3: Product level	Production of 1kg of liveweight salmon, at harbour gate

DESCRIPTION OF THE CASE

See summary description of methodology here

Context

Introduced as a solution to partially solve the environmental issue linked with meat production, the fish production industry is currently in the spotlight. Wild marine resources are overexploited and threatened; there are numerous calls to keep fishing activities within sustainable boundaries. Wild caught fishing is not sufficient to provide for consumption demand, resulting in a dramatic growth in aquaculture in the last three decades [1, 2].

In order to assess the ecological impacts of fisheries and aquaculture, we conducted a study on the case of Norwegian Atlantic salmon (Salmo salar). This study accounts for the 5 drivers on biodiversity identified by IPBES [3]. We look at a generic case study on salmon aquaculture production in Norway. Our goal with this study is to adapt the PBF framework to aquaculture systems.

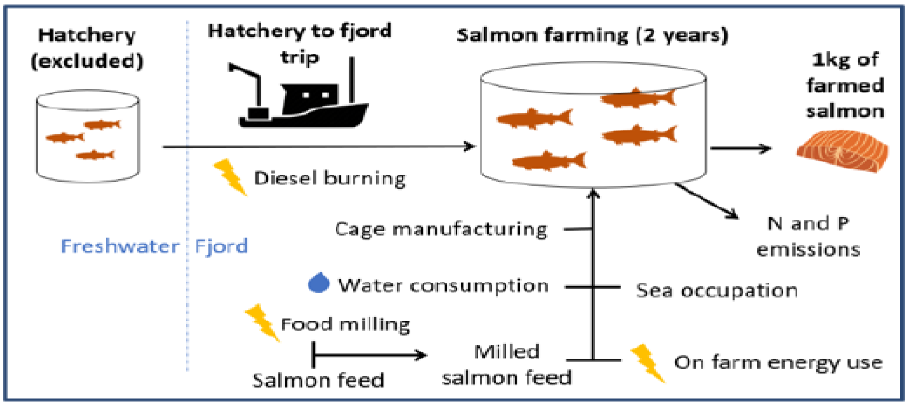
Our case study also includes a benchmark against wild caught salmon, keeping in mind that this limited resource is unable to provide for the total salmon consumption demand.

Boundaries

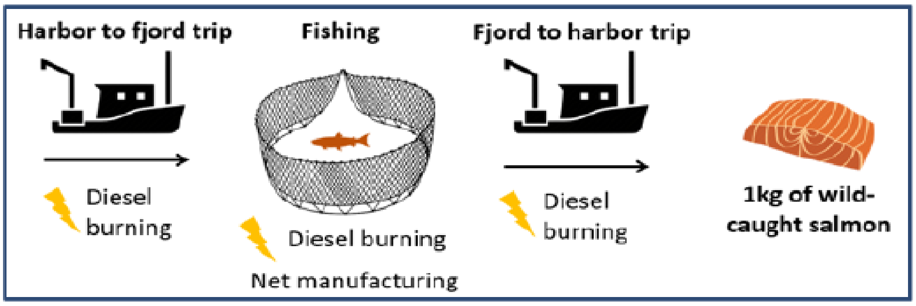
Boundaries are 'cradle to harbour gate', as described in the figures below. Value chain focus is production of liveweight salmon at harbour gate (functional unit). Production of salmon at harbour gate is national average Norway salmon, both for aquaculture and for the fishing benchmark. The upstream value chain is accounted for, and for Norway farmed salmon, part of the salmon feed is coming from Peruvian seas [4]. For farmed salmon, the hatchery phase has been excluded, assuming it is marginal in the overall impacts due to the limited time and feed needed in that phase. Smolders transport to fjord is included.

The three first MEA/IPBES drivers, i.e. habitat change, pollution and climate change, are assessed with the ReCiPe 2016 Life Cycle Impact Assessment method [5], according to current PBF method. ReCiPe enables to aggregate scores on the three drivers into a single score in Potential Disappeared Fraction of species (PDF). With this case study, we have further developed PBF on both other drivers: overexploitation and invasive species. Those developments are based on LCA and ecology literature.

Overexploitation is assessed for two fish stocks of interest in our study: Atlantic salmon in Norwegian Sea and Peruvian anchovy in Peru, as it is the main fish feed of "average" farmed salmon. Invasive species is assessed for escaped farmed salmon.



Farmed salmon



Wild-caught salmon

Location and scale

Aquaculture and fisheries of salmon in Norway

Types of pressures

Pressures	Terrestrial	Freshwater	Marine
Land use change			Sea occupation of aquaculture cages in fjords
Climate change	yes	yes	
Pollution	Terrestrial acidification. Tropospheric ozone	Freshwater eutrophication	Marine eutrophication
Direct exploitation			Overfishing of wild salmon and fish feed for farmed fish (Peruvian anchoveta)
Invasive species			Escaped salmon from aquaculture
Other			Disturbance of food webs in case of aquaculture. Antibiotics

Collected data on economic activities, pressures, state and impacts

Primary data	Secondary data	Modelled data
Economic data		
See footnote [1] Data on fish yields, fuel (and electricity) consumption Data on feed composition and quantity for aquaculture Smolt transport Occupation of cages in fjords	*See footnote* [2] Nitrogen and Phosphorus emissions from farmed fish [6] Boat construction and infrastructure (cages..) : data from ecoinvent [7] Feed production data from ecoinvent [7] and Agribalyse [8]	
Challenges		
Tracing the origin and manufacturing practices for feed production. We use original information when available, otherwise "averages". For practices, we use average ones as available in secondary database [7], [8]	Alternative feed data such as 'feed from insects' does not currently exist in LCA databases. If needed in ecodesign scenarios, data should be gathered from available literature, or approached by a proxy with data quality to be reported.	
Pressures		
		Cause effect chain models: - Modelled data from LCIA method for climate change, pollution and habitat change pressures. - Overexploitation - Invasive species (qualitative model)
Challenges		
Pressures assessed from literature, no specific company data in this generic case study.		Standard LCIA models are not harmonised in terms of taxa coverage or reference states.
State		
		Current stocks of feed fish used for overexploitation model [9]
Challenges		
No state primary data available for marine products		
Impacts		

[1] This is a generic case study in which only available data from literature have been used. However, this cell has been filled in as if it were from a farmed fish producer perspective.

[2] This is a generic case study in which only available data from literature have been used. However, this cell has been filled in as if it were from a farmed fish producer perspective.

Primary data	Secondary data	Modelled data
		Modelled impact assessment with LCIA method for 3 pressures, looking at 'Ecosystem Quality' endpoint. Modelled impact based on [10] for overexploitation. Proposed new semi quantitative method to assess impact from invasive species (farmed salmon).
Challenges		
		Add up impact of 5 pressures in a single indicator in PDF.

What was the role of qualitative information?

- **Modelling :** Qualitative information is used in the invasive species scoring system. The role is to inform risk matrix.
  Limitation of overexploitation model is also qualitatively reported, as it does not relate to the impact of removing a given fish stock to the entire marine ecosystem quality.
- **Pressure assessment**: Some pressures are not reported quantitatively for the pollution driver, especially pressures from antibiotic application. They are reported qualitatively.
- **Input data:** Qualitative assessment has to be reported.

Baseline/reference situation

For climate change, pollution and habitat change baseline is LCIA model’s and refers to current situation. For overexploitation and invasive species baseline is current situation.

Required efforts for the measurement

This case study is theorical one. In case filled in by farm salmon producer, we expect the company to spend 5-10 man-days (data collection, ...) and the consultant 10-20 days (modelling, report)

Required skills to complete this exercise

LCA and ecology specialists

Results and application

Figure 1a gives a good insight in how the biodiversity footprint of farmed salmon is different from the footprint of wild caught salmon, while Figure 1b shows the dominant influence of feed in the biodiversity footprint of farmed salmon. Figure 2 shows the negative impact on Peruvian anchovy stocks by overexploitation for being used as feed for farmed salmon, while the impact on wild salmon stocks is under control by applying maximum quota. Figure 3 shows the invasive species results (impact of escaped farmed salmon on native ecosystem).

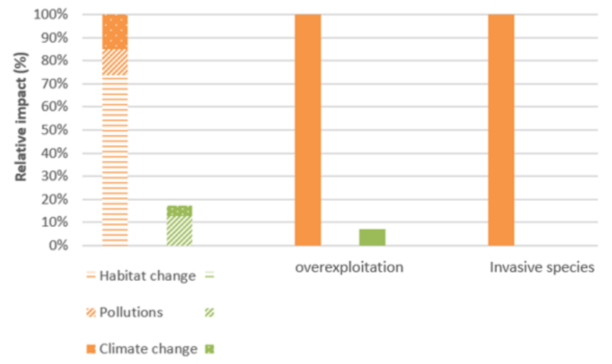


Figure 1a: Relative impact in % of farmed salmon (orange) compared to wild caught salmon (green). LCA method is ReCiPe 2016 (H) endpoint value for 'ecosystem quality'

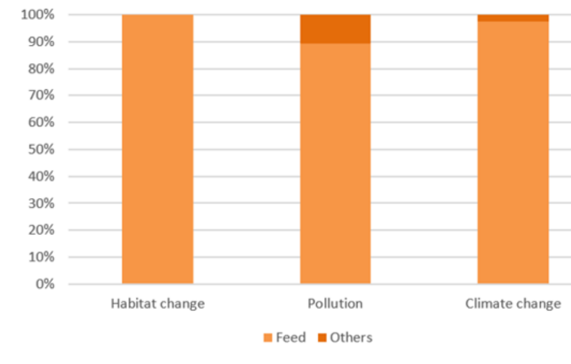


Figure 1b: Share of impacts due to feed for farmed salmon

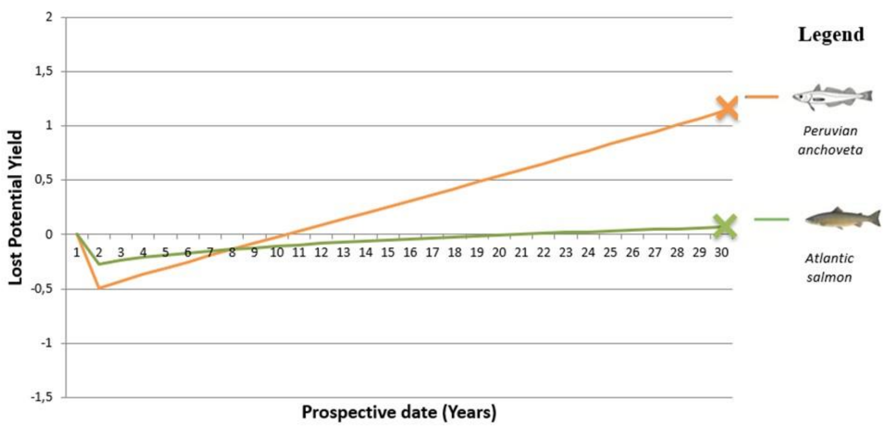


Figure 2 : Lost Potential Yield and vulnerability of fish stocks according to *Emanuelsson et al. (2014).* The X axis represents the prospective date at which the yield is potentially lost. The Y axis represents the value of this lost in proportion of the current catch. Negative LPY values correspond to the period of recovery which is needed to sustainably manage the stock.

Criticality (C)		Behavior								
		-27	-9	-3	0	3	9	27	81	243
Effect	16	-432	-144	-48	0	48	144	432	1296	3888
	8	-216	-72	-24		24	72	216	648	1944
	4	-108	-36	-12		12	36	108	324	972
	2	-54	-18	-6		6	18	54	162	486

Criticality scale		
Positive	-432	-1
Minor	0	36
Serious	37	144
Major	145	486
Disastrous	487	3888

Wild-Caught
Not relevant

Farmed
Invasive species = farmed salmon

Figure 3 : invasive species results. The method assesses the potential behavior of invader (through various pathways : predation, competition for territory and transmission of parasites) with the potential effect on the native ecosystem, and derives a qualitative rating plotted into a criticality matrix. Results for wild-caught salmon are not relevant (assumed to be equal to zero) and are moderate for farmed salmon.

Interpretation of results and impact on decision-making

Results show that farmed salmon has a greater impact on ecosystems than wild caught salmon (see Figure 1a and Figure 1b), mostly linked to feed production. The low impact of overexploitation for wild-caught salmon illustrates the benefits of the recent Norwegian regulation on salmon fishing: catches of wild salmon have reached but do hardly excess Maximum Sustainable Yield (MSY).

There is room for improvement for farmed salmon, with feed production being the major issue, on habitat change, pollution, climate change and overexploitation (of Peruvian Anchoveta) drivers. Further research is needed to look at more sustainable feed also accounting for feed nutrition requirements.
For the invasive species driver, we consider the potential of the escaped seafood to be invading the ecosystem. Indeed, literature highlights the potential of escaped farmed salmon to disrupt local ecosystems, especially through the transmission of sea lice. Our method shows a moderate impact of escaped salmons, aligned with the relatively low invasiveness of escaped salmon compared to other marine invaders (see Figure 3).

This first generic study demonstrates the implementation of PBF on seafood products. It has enabled some specific developments PBF had been adapted to seafood sector, in two major aspects: i) regarding overexploitation of fish resources, entering directly wild caught or entering in the composition of feed for aquaculture and ii) regarding farmed seafood as a potential invasive alien species in the ecosystem.
Based on PBF hotspots, this case study also enables to list data requirements for analysing the aquaculture production. For aquaculture, it shows that feed quantity and composition is crucial for the assessment.

We expect the next iteration in this sector to compare eco-design options in real farming systems.

STRENGTHS AND LIMITATIONS OF THE APPLIED MEASUREMENT APPROACH IN THIS SPECIFIC CASE

Self-assessment

Relevance	
Strengths	• It enables to compare biodiversity impacts of seafood products over their value chain, therefore capturing the main impactful steps of the product, to be used for ecodesign purposes of seafood producers. Special focus on overexploitation which is crucial to account for in this sector. Also accounting for escaped farmed seafood as a potential invasive species within the ecosystem, including through disease spreading. • Geographical specificities are captured by looking at the marine biome where the species are fished.
Limitations	• Knowledge on marine ecosystems is less abundant than for terrestrial. It is a challenge in this study, especially for spatialisation.
Opportunities for improvement	• Generic information to be adapted to real business case study. Next iteration to be on comparison of different aquaculture production systems and providing spatialized results on disturbance to marine ecosystems for some pressures (marine eutrophication; seabed occupation ..)
Completeness	
Strengths	• Our study covers the 5 MEA/IPBES drivers over the whole value chain, including overexploitation and invasive species.
Limitations	• Hatchery has been excluded from the boundary of the study. Impacts are assumed to be limited. • By using aggregated characterization factors, the underlying LCA model (ReCiPe) does not provide detailed results on specific taxa. • Model on invasive species is limited (single species) and is new (only model existing to determine the impact on biodiversity from invasive species). • Important pressures are not covered by the measurement approach, mainly related to farmed salmon e.g. disturbance of food webs in case of aquaculture (due to decline of anchovy populations), spreading of antibiotics in freshwater and marine environments, indirect impacts on marine biodiversity due to population decline of anchovy.
Opportunities for improvement	• Include hatchery in the scope and check related contribution on biodiversity. • Improve overexploitation model with upcoming research, potentially enabling to measure it in PDF. • Our model on invasive species might help provide new features to develop the subject. • On-going contribution to international and European Commission efforts on harmonization of biodiversity metrics.
Rigor	
Strengths	• Inclusion of overexploitation, the main driver of biodiversity loss in marine ecosystems [3], is addressed
Limitations	• Overall limited quality of economic data. For farmed salmon, combination of data from different literature sources for e.g. feed composition and emissions from faeces. For wild-caught salmon, proxies are used for fishing distances and related fuel consumption. • For impact assessment, the limits are the same as any LCA modelling, especially on the fact that calculated impacts are most of the time "potential impacts"
Opportunities for improvement	• Currently designing confidence indicators for each pressure's assessment (case study dependent).

Replicability	
Strengths	• Methodology is fully transparent ; initial framework described in Emanuelsson et al. (2014) [11] ; additional impacts are described in upcoming peer-reviewed scientific publications (see below). • Computation of overexploitation indicator is readily available for 70 species.
Limitations	• Technical knowledge of LCA is required. • Technical knowledge of ecology required to assess invasive species indicator. • Some species are missing for easy replicability of overexploitation indicator over the whole spectrum of fished species.
Opportunities for improvement	• Two publications underway (overexploitation and invasive species).
Aggregation	
Strengths	• Aggregation of three of the five pressures is straightforward (habitat change, pollution, climate change) as these are all expressed in PDF.
Limitations	• Scores for overexploitation and invasive species are not expressed in PDF. Aggregation of the five pressures is challenging.
Opportunities for improvement	• Opening for quantifying overexploitation in PDF in an upcoming publication of Helias and Bach [12]
Communication	
Strengths	• Results are mostly presented in a graphical way.
Limitations	• Case study is generic. Therefore, no alignment with PBF communication and no feedback from business at this stage.
Opportunities for improvement	• Expecting real business case study to align and challenge communication.
User friendliness	
Strengths	• Mostly relies on available data or LCA studies. • Approach is familiar to LCA practitioners
Limitations	• Assessment largely facilitated with the use of a LCA software, such as SIMAPRO or openLCA, and background data, such as ecoinvent [7] • Experts are needed to complete assessment, especially for aquaculture systems and the related invasive species indicator.
Opportunities for improvement	• Data collection tool adapted to the sector (especially farmed seafood). • Collection of ecological data for the main farmed species in the various regions of the world could be useful to streamline assessment of invasive species indicator.
Investment	
Strengths	• Open-source data. Reasonable investment of time.
Limitations	• Assessment largely facilitated with the use of a LCA software and background LCA data. • Need for expert knowledge.
Opportunities for improvement	• Has not been tested on a 'real business' case study'. We are currently looking for one.

Overall assessment

PBF method has been refined and adapted for seafood with this case study. Further developments have been conducted on 'overexploitation' and 'invasive species'. Overexploitation, one of the main impact pathways related to marine biodiversity loss is quantitatively assessed, with a promising avenue to be aggregated in the PDF unit based on the upcoming publication of Helias and Bach [12]. We propose a new model on invasive species, based on ecology; it is however limited to the farmed species (single species). Further improvements are needed for aquaculture in addressing missing pressures (e.g. application of antibiotics), and spatialize impacts (e.g. seabed occupation, eutrophication...).

The case study highlights **the need to focus on feed composition and origin** to design better aquaculture farming systems and raises attention on the potential impact of escaped individuals in aquaculture farming systems.

The next step for PBF would be to **compare different seafood farming systems based on industry data**. This will enable to **close gaps in the method,** and further proof-test it with business; this would also contribute to enhance communication and user-friendliness.

Case study description and self-assessment carried out by

Anne Asselin, Aurore Wermeille (Sayari)

More information on the measurement approach can be found here:

A. Asselin *et al.*, « Product Biodiversity Footprint – A novel approach to compare the impact of products on biodiversity combining Life Cycle Assessment and Ecology », *Journal of Cleaner Production*, 2019, doi: 10.1016/j.jclepro.2019.119262.

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