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EFFOP Position Paper

Technical Review of the European Commission Report: *Replacing Fish-Based Feed with Algae-Based Feed in EU Aquaculture*

This document provides a technical review of the European Commission report "Replacing Fish-Based Feed with Algae-Based Feed in EU Aquaculture". The objective is not to dispute the important role that algae and other novel ingredients are expected to play in the future development of aquaculture feeds, but rather to assess whether the report presents a balanced, evidence-based and scientifically robust evaluation of marine ingredients and the the challenge of feed strategies in the future of aquaculture nutrition.

The continued expansion of global aquaculture will require an increasingly diverse portfolio of feed ingredients to meet growing demands for aquatic food production while maintaining high standards of environmental, economic and social sustainability. Algae, alongside terrestrial proteins, plant-derived ingredients, microbial proteins and marine ingredients, each have important characteristics that can contribute to future feed formulations. **However, no feed ingredient should be evaluated in isolation, nor should any single ingredient be regarded as a universal solution.** Rather, ingredient selection should be based on a comprehensive assessment of nutritional value, ingredient functionality, environmental performance, resource efficiency, economic viability, technology readiness, scalability and practical application within commercial feed formulation.

This review identifies a number of areas where the Commission report appears to provide an incomplete assessment of marine ingredients and the broader role they play within modern aquaculture feeds. Particular attention is given to the treatment of forage fisheries, fish processing by-products, ingredient functionality (including palatability and feed intake), nutritional value, life cycle assessment, sustainability metrics, technology readiness, economic feasibility and practical feed formulation. In several instances, the report emphasises individual sustainability metrics or ingredient characteristics without considering the wider body of evidence or the complementary roles that different ingredient classes play within commercial aquaculture.

Where appropriate, comparisons are made with recent peer-reviewed literature, including the recent review by Glencross et al. (2024)[1], which evaluates marine ingredients, plant proteins, terrestrial animal proteins and novel protein sources using a consistent scientific assessment framework coupled with a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis. This provides an appropriate benchmark against which many of the conclusions presented in the Commission report can be evaluated.

[1] Glencross, B., Ling, X., Gatlin, D., Kaushik, S., Øverland, M., Newton, R., & Valente, L. M. (2024). A SWOT analysis of the use of marine, grain, terrestrial-animal and novel protein ingredients in aquaculture feeds. Reviews in Fisheries Science & Aquaculture, 32(3), 396-434.

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The report frames the discussion as "fish versus algae" rather than "fish and algae"

Throughout the report, the transition towards more sustainable aquaculture feeds is consistently framed as the **replacement** of fish-based ingredients with algae-based alternatives, rather than the **optimization and diversification** of feed formulations using complementary ingredient sources. This contrasts with the long-established scientific approach to aquaculture nutrition, where feed formulation is based on combining ingredients with complementary nutritional and functional characteristics, rather than seeking a single replacement ingredient[2,3]

This concern has also been raised previously by EFFOP, the Aquaculture Advisory Council (AAC) and FEFAC during discussions on the EU Algae Initiative and the future direction of EU feed policy.

A key consideration largely absent from the report is that **algal oils and algal meals are themselves marine ingredients**. They are already being incorporated into commercial feed formulations **alongside** fishmeal and fish oil to complement existing nutritional strategies, rather than replacing marine ingredients entirely. Consequently, the question should not simply be:

"How can fish-based ingredients be replaced?"

but rather:

"How can algae and other novel ingredients complement responsibly sourced marine ingredients to optimise the nutritional, environmental and economic performance of aquaculture feeds?"

The report overlooks the central role of fish processing by-products

The report gives only limited consideration to seafood processing side streams before returning to the question of replacing wild-caught fish with algae. In doing so, it overlooks one of Europe's most established and successful examples of industrial circularity. Today, fish processing by-products constitute a significant portion of the raw material used for European marine ingredient production, transforming material that would otherwise have low-value uses or become waste into high-value feed ingredients for aquaculture and livestock. Across Europe, EFFOP members alone utilise an estimated **1–1.5 million tonnes**[4] of fish processing by-products annually, producing approximately **280,000 tonnes of fishmeal** and **70,000 tonnes of fish oil**.

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[2] Turchini, G. M., Trushenski, J. T., & Glencross, B. D. (2019). Thoughts for the future of aquaculture nutrition: realigning perspectives to reflect contemporary issues related to judicious use of marine resources in aquafeeds. *North American Journal of Aquaculture*, *81*(1), 13-39.
[3] Glencross, B. D., Booth, M., & Allan, G. L. (2007). A feed is only as good as its ingredients–a review of ingredient evaluation strategies for aquaculture feeds. *Aquaculture nutrition*, *13*(1), 17-34.
[4] European Fishmeal and Fish Oil Producers (EFFOP): Marine Nutrients Europe. (2026). Internal data

This is entirely consistent with the objectives of the EU Circular Economy Action Plan and the waste hierarchy, both of which prioritise the recovery and valorisation of unavoidable by-products before seeking alternative primary resource streams. Rather than focusing predominantly on replacing "fish-based" ingredients, policy should first seek to maximise the utilisation of existing circular resources already generated within European seafood value chains.

The scale difference is also significant. European "fish-based" marine ingredient producers already produce ca. 350.000 tonnes of marine ingredients from fish processing by-products every year—this is orders of magnitude greater than the current production volumes of algal feed ingredients in Europe. More importantly, one of the greatest near-term opportunities to increase the supply of sustainable feed ingredients lies in improving the collection, utilisation and policy framework surrounding fish processing by-products, while continuing to develop algae as a complementary resource rather than positioning it as a direct substitute.

The report assumes that a lower FFDR equates to greater sustainability

Throughout the report, Fish Feed Dependency Ratios (FFDR) are implicitly treated as a measure of sustainability, with lower FFDR values presented as an inherently desirable outcome. However, FFDR was developed as a resource accounting metric rather than an environmental assessment tool. It estimates the quantity of marine ingredients originating from wild fish required to produce farmed fish, but it does not evaluate the overall sustainability of those ingredients. Importantly, FFDR provides no information on greenhouse gas emissions, biodiversity impacts, ecosystem management, resource efficiency, circularity, fishery governance or responsible sourcing. **Nor does it distinguish between marine ingredients originating from a well-managed fishery operating under science-based harvest strategies and those sourced from poorly managed fisheries**. Equally, FFDR does not recognise the value generated through the efficient conversion of low-value marine biomass into high-value, nutrient-dense food products. For example, forage fish such as Peruvian anchoveta may have a first-sale value of only around USD 300 per tonne, yet can ultimately contribute to the production of Atlantic salmon worth approximately USD 8,000 per tonne. Such resource efficiency is entirely absent from FFDR calculations.

More fundamentally, replacing one feed ingredient with another should not automatically be assumed to improve sustainability. Every ingredient carries its own environmental footprint, resource requirements and trade-offs, and these can only be assessed through comprehensive environmental methodologies rather than a single resource-use indicator. Consequently, a reduction in FFDR cannot, in itself, be interpreted as an improvement in environmental sustainability.

Recent sustainability assessments have increasingly recognised these limitations and advocate for holistic evaluations using multiple environmental indicators, particularly life cycle assessment (LCA), when comparing marine ingredients with alternative feed resources (e.g. Malcorps et al., 2026[5]). Indeed, recent work has shown that despite substantial reductions in FFDR over the past two decades, the carbon footprint of salmon aquafeeds has increased by more than **300%[6]**, this is a shift that has paradoxically been supported via endorsement of the FFDR in some sustainability schemes.

Ironically, the report itself acknowledges that life cycle assessments frequently demonstrate favourable environmental performance for forage fisheries owing to their relatively low fuel use and associated greenhouse gas emissions. This evidence is subsequently discounted because current LCA methodologies do not comprehensively capture biodiversity impacts. While improving biodiversity assessment within LCA remains an important area of methodological development, it does not justify replacing one imperfect indicator with another worse performing one. Therefore, when using or interpreting them, it is essential to understand both what they measure and, more importantly, what they do not.

Furthermore, European “fish-based” marine ingredients are produced within one of the world's most transparent and scientifically governed fisheries management systems. Fisheries operate under independent scientific advice provided by ICES and are managed through EU and national frameworks incorporating precautionary harvest strategies, quota management, comprehensive monitoring, control and increasingly ecosystem-based approaches. Biodiversity considerations are therefore not ignored; they are embedded directly within fisheries management through stock assessments, ecosystem modelling, bycatch monitoring, protection of endangered, threatened and protected (ETP) species, spatial management measures and the continuous collection of scientific data used to reduce uncertainty and improve future management advice.

Many European fisheries are also independently verified through GSSI-recognised certification schemes, including MarinTrust, the Iceland Responsible Fisheries Standard and the Marine Stewardship Council (MSC), which require assessments of stock status, ecosystem impacts, bycatch, habitat interactions and management effectiveness. Together, these schemes underpin the ASC Responsible Sourcing Framework. The omission of these well-established governance and biodiversity safeguards from the report presents an incomplete picture of the sustainability framework under which European “fish-based” marine ingredients are produced.

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[5] Malcorps, W., Newton, R., Horn, S., Kok, B., Troell, M., & Little, D. C. (2026). Fish as Food or Feed? Aligning FIFO with LCA and Food System Objectives. *Reviews in Fisheries Science & Aquaculture*, 1-15.
[6] Kok, B., Malcorps, W., Santos, M. J., Newton, R. W., Harmsen, R., & Little, D. C. (2026). Sustainable aquafeed? The devil is in the detail. *Journal of Cleaner Production*, *546*, 147666.

Similarly, the global marine ingredients sector is investing in comprehensive environmental assessments using Product Environmental Footprint Category Rules (PEFCR) and the Global Feed LCA Institute (GFLI) methodology to produce internationally harmonised and independently reviewed life cycle assessments. Recent work applying these standardised methodologies has demonstrated that **marine ingredients often exhibit lower global warming, land-use and water-use footprints than many commonly used terrestrial feed ingredients**, although the environmental footprint varies according to fishery fuel intensity[1]. Applying these same methodologies to emerging algal ingredients would enable meaningful comparisons based on measured environmental performance, rather than relying primarily on simplified indicators such as FFDR.

Summary of Evidence omitted or underrepresented when discussing FFDR

- Peruvian anchoveta contributes approximately **15% of global fish landings** while accounting for **only ~3% of global fisheries GHG emissions**, illustrating the exceptionally high resource efficiency of industrial small pelagic fisheries[1].
- FFDR and FIFO do not account for nutrient retention, broader food-system dynamics, market demand for fishery resources, the multifunctionality of marine co-products or the growing contribution of fish processing by-products
- Modern FIFO methodologies have been developed to integrate with **ISO 14040, PEFCR and GFLI-compliant Life Cycle Assessments**, enabling marine ingredient dependency metrics to be interpreted alongside measured environmental impacts rather than in isolation
- Replacing marine ingredients in aquaculture feeds alone could require more than 47,000 km^2 of additional agricultural land, highlighting the importance of evaluating ingredient substitution through holistic land-use trade-offs rather than simplified metrics such as FFDR[7].
- No quantitative assessment is provided of the algal biomass, cultivation capacity, energy demand or nutrient inputs that would be required to replace current marine ingredient production at commercial scale. However one estimation[8] exploring this estimated placing **Thailand's fishmeal production alone (approximately 5% of global production) would require around *ca.* 100-120 fully commercial facilities**, illustrating the scale of infrastructure required for large-scale substitution.

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[7] Leadbitter, D., Aebischer, N. J., Auchterlonie, N. A., Benton, T. G., Froehlich, H. E., Hall, S., ... & Hilborn, R. (2025). Biodiversity Consequences of Replacing Animal Protein From Capture Fisheries With Animal Protein From Agriculture. *Reviews in Fisheries Science & Aquaculture*, 1-13.
[8] Beal, C.M., Gerber, L.N., Thongrod, S., Phromkunthong, W., Kiron, V., Granados, J., Archibald, I., Greene, C.H. and Huntley, M.E., 2018. Marine microalgae commercial production improves sustainability of global fisheries and aquaculture. *Scientific Reports*, *8*(1), p.15064.

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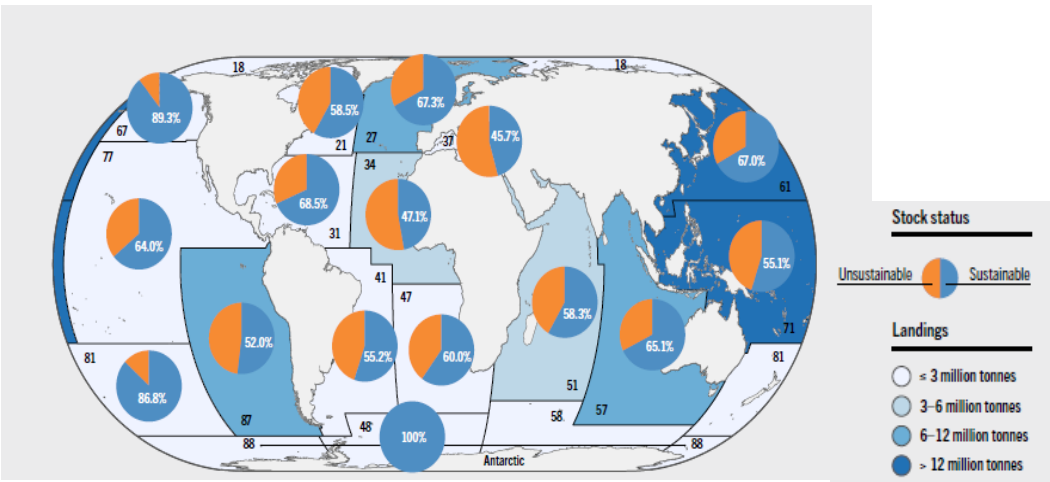
The report overgeneralises the sustainability status of global fisheries

The report states that **37% of global fish stocks are overfished**, but presents this statistic without considering its relevance to the fisheries that supply marine ingredients. While factually correct, this global figure aggregates fisheries with widely differing management systems, stock status and governance arrangements. As a result, it implies a common sustainability profile across all forage fisheries when, in reality, substantial differences exist. A recent study[9] concluded that **small pelagic fisheries are among the most sustainably managed fisheries globally**, demonstrating that sustainable exploitation is **not an aspirational concept but an achievable management outcome** when robust scientific advice is translated into effective policy and fisheries management. The report misses an important opportunity to distinguish between fisheries operating under such science-based management systems and those where governance remains weak.

Many European fisheries are also independently verified through internationally recognised certification schemes, including MarinTrust, the Marine Stewardship Council (MSC), Iceland Responsible Fisheries (IRF) and Certified Seafood International (CSI), several of which are benchmarked by the Global Sustainable Seafood Initiative (GSSI) and contribute to the ASC Responsible Sourcing Framework. A more balanced assessment would therefore distinguish between **well-managed fisheries, fisheries undergoing improvement and unsustainably managed fisheries**, rather than relying on a single global statistic that does not reflect the fisheries supplying European marine ingredients.



[9] Hilborn, R., Buratti, C.C., Díaz Acuña, E., Hively, D., Kolding, J., Kurota, H., Baker, N., Mace, P.M., de Moor, C.L., Muko, S. and Osio, G.C., 2022. Recent trends in abundance and fishing pressure of agency-assessed small pelagic fish stocks. *Fish and Fisheries*, *23*(6), pp.1313-1331.

Regional variation[10] in the proportion of biologically sustainable (blue) and biologically unsustainable (orange) fish stocks across FAO Major Fishing Areas. The figure illustrates that stock status differs markedly between regions, reflecting differences in fisheries management and governance rather than a uniform global pattern

The contaminant section presents an incomplete picture

The report correctly notes that algal oils generally contain lower concentrations of dioxins and polychlorinated biphenyls (PCBs) than marine fish oils. However, the discussion is largely one-sided and gives little consideration to the extensive regulatory framework, processing technologies and long-term improvements that have substantially reduced contaminant exposure from marine ingredients.

The implicit comparison presented is one of "algae = clean" versus "fish oil = contaminated", whereas the reality is considerably more nuanced. Fish oil placed on the European market is subject to some of the world's most stringent contaminant legislation. In line with the ALARA principle, the European Commission further strengthened these requirements in 2026 by reducing the maximum permitted concentration of dioxins and dioxin-like PCBs in marine oils from **5.0 ng WHO-TEQ kg^{-1}** to **3.5 ng WHO-TEQ kg^{-1}**. Importantly, oils exceeding these limits are **not simply excluded from the value chain**. Modern fish oil refining technologies, including activated carbon treatment, are highly effective at removing dioxins and PCBs, with the contaminants subsequently concentrated in spent filter media that are safely disposed of through high-temperature incineration. As a result, the contaminant burden is removed from both the feed chain and the wider environment.

This process provides an often-overlooked environmental benefit. By removing persistent organic pollutants from contaminated fish, the marine ingredients industry contributes to reducing the overall contaminant burden within the Baltic Sea ecosystem. Previous assessments[11] estimated that industrial fisheries and fish oil refining could remove **up to approximately 13% of the annual dioxin inputs** to the Baltic Sea through this process.

The report underplays ingredient functionality and nutrient density

The report largely treats feed ingredients as interchangeable nutrient carriers, with particular emphasis on EPA and DHA. This is a narrow interpretation of aquafeed formulation. In practice, ingredients are evaluated not only by their proximate composition, but by their contribution to **digestible nutrient supply, amino acid balance, lipid quality, mineral bioavailability, digestibility, palatability, pellet quality, processing behaviour, inclusion limits, ingredient consistency, cost and responsible sourcing**. These characteristics

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[10] FAO, *The State of World Fisheries and Aquaculture 2026 (SOFIA 2026)

[11] Gustavson, K., Bjergström, M., Aro, E., Hedman, J., Strandmark, A., Bignert, A., MacKenzie, B.R. and Hagebro, C. (2010). *Feasibility of Removal of Dioxin and Dioxin-like PCBs by Intensive Fishery of Herring and Sprat in the Baltic Sea*. TemaNord 2010:534. Copenhagen: Nordic Council of Ministers. ISBN 978-92-893-2060-3.

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Marine Nutrients Europe

interact within complete diets and cannot be assessed by considering one or two nutrients in isolation.

This systems-based approach has underpinned decades of aquaculture nutrition research[1,2,3,12,13]. Rather, ingredients are assessed according to their overall contribution to animal performance, nutrient utilisation, feed manufacture and economic efficiency within practical commercial formulations. This explains why marine ingredients have remained the benchmark against which alternative ingredients are evaluated despite decades of replacement research. Fishmeal provides highly digestible protein, an excellent essential amino acid profile, highly bioavailable phosphorus and trace minerals, naturally occurring feeding stimulants, low carbohydrate content and excellent processing characteristics[1]. Fish oil provides EPA and DHA in a highly bioavailable form while also contributing to feed manufacture and product quality[1]. These characteristics are not independent: palatability influences voluntary feed intake, feed intake drives growth, digestible nutrient availability determines nutrient retention, while mineral bioavailability influences both fish performance and nutrient discharge to the environment[13].

he report therefore overlooks a fundamental principle of aquaculture nutrition: **replacing a nutrient is not equivalent to replacing the functionality of an ingredient**. Although algal meals and oils represent highly promising marine ingredients and are expected to play an increasingly important role in future aquaculture feeds, their evaluation must extend well beyond EPA and DHA content alone. Practical considerations include digestibility, processing requirements, inclusion limits, ingredient consistency, pellet quality, feed intake, production economics and manufacturing scalability. For many commercially relevant algal ingredients, robust cell-wall structures and complex polysaccharides can reduce nutrient availability unless additional processing is applied, increasing both production complexity and cost[14]. Consequently, nutrient composition alone provides an incomplete assessment of ingredient value, as the biological availability of nutrients depends on both ingredient processing and animal physiology. The relevant scientific question is therefore not whether algae can replace fishmeal or fish oil, but **how algal and marine ingredients can be combined to maximise nutritional performance, sustainability and resource efficiency within commercial aquaculture feeds.**

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[12] Gatlin III, D.M., Barrows, F.T., Brown, P., Dabrowski, K., Gaylord, T.G., Hardy, R.W., Herman, E., Hu, G., Krogdahl, Å., Nelson, R. and Overturf, K., 2007. Expanding the utilization of sustainable plant products in aquafeeds: a review. *Aquaculture research*, *38*(6), pp.551-579.
[13] Glencross, B. D. (2020). A feed is still only as good as its ingredients: An update on the nutritional research strategies for the optimal evaluation of ingredients for aquaculture feeds. *Aquaculture Nutrition*, *26*(6), 1871-1883.
[14] Becker, E.W. (2007). Micro-algae as a source of protein. Biotechnology Advances, 25(2), 207–210. https://doi.org/10.1016/j.biotechadv.2006.11.002

The report recommends policy intervention before markets are ready and gives insufficient consideration to food security

Several of the report's recommendations—including reducing FFDR through policy targets, tightening contaminant regulations, removing **"existing subsidies"** (despite no equivalent subsidy framework existing specifically for European marine ingredient producers) and introducing fiscal incentives for alternative ingredients—extend beyond scientific assessment into policy prescription. However, these recommendations are made without a corresponding assessment of whether algal production currently possesses the production capacity, technological maturity, economic competitiveness or supply-chain resilience required to meet the demands of the aquaculture sector at commercial scale. As a result, the report moves towards advocating a specific policy pathway, without adequately considering contrary evidence or demonstrating that the necessary technical, economic and market conditions exist to support such a transition

More fundamentally, the report largely frames forage fisheries as feed inputs rather than as components of a broader food system. Consequently, relatively little attention is given to nutrient efficiency, food security, the strategic role of marine ingredients in increasing global seafood production or the contribution of precision nutrition to improving resource utilisation. This represents a significant omission. The purpose of marine ingredients is not simply to convert wild fish into farmed fish, but to maximise the production of highly nutritious seafood from marine biomass that is often of limited direct value for human consumption. Modern aquaculture nutrition therefore uses marine ingredients strategically, typically at relatively low inclusion levels, to enable the efficient production of substantially larger quantities of seafood. Current estimates[15]suggest that **1 kg of responsibly sourced wild fish** used for marine ingredients can contribute to the production of **at least 4 kg of farmed seafood** and in some cases, deliver a **net increase in the production of long-chain omega-3 fatty acids (EPA and DHA)** available for human consumption[5].

A more balanced assessment would therefore evaluate marine ingredients within the context of **food system efficiency, nutrient delivery and food security**, rather than primarily through the lens of ingredient substitution. As recognised by recent work on nutrient retention and marine ingredient efficiency[5] the relevant policy objective should be to maximise the availability of essential nutrients for human populations while minimising environmental impacts—not simply to minimise the use of marine ingredients.

[15] Glencross, B. D., Bachis, E., Robb, D., & Newton, R. (2024). The Evolution of Sustainability Metrics for the Marine Ingredient Sector: Moving Towards Holistic Assessments of Aquaculture Feed. *Reviews in Fisheries Science & Aquaculture*, *32*(4), 545–561. https://doi.org/10.1080/23308249.2024.2337426