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# Dietary shifts and the need for increased sustainability approaches in the global aquaculture seafood system

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Recent shifts in the global dietary preferences have indicated the fast-growing choice for plant-based, or meat-reduced diets. Among the motivations for such choices, which are increasingly advocated by nations and environmental institutions, is the major concern with global environmental sustainability and impacts of food production systems. Incontestably, the animal food source industry is extremely diverse, and seafood production through the aquaculture value chain remains unfamiliar to key stakeholders possibly leading to an uncomprehensive view and often biased perception of the farming industry within the environmental context. Accordingly, I discuss the importance of seafood production systems, such as the fastest seafood production that is the aquaculture sector, to increase their focus on the sustainability arena with more substantial and effective improvements for sustainable production, and most importantly, concomitantly informing end consumers. I mention examples of types of sustainability efforts that can be implemented and highlight the urgency of actively informing customers about implemented practices.

KEYWORDS

**dietary shifts, meat-reduced diets, seafood, aquaculture, environmental sustainability, food production systems**

## Introduction

Discussions about the need for more sustainable food systems have driven major changes in food production and consumption (United Nations, 2023). Meat-reduced or meatless diets have been adopted globally influenced by various factors, such as regional context (availability), culture and beliefs, personal preferences, animal welfare concerns, health promotion, and increasingly, environmental sustainability (Vanderlee et al., 2022); the latter two arguably reflecting up-to-date scientific knowledge. With growing awareness of planetary challenges, concerns about the environmental consequences of meat production have increased exponentially, and more sustainable diets including plant-based food are being suggested as a way to help countries achieve the Sustainable Development Goals (SDGs; Willett et al., 2019) and adhere to the climate goals set by the Intergovernmental Panel on Climate Change (IPCC; Mbow et al., 2019). As a result, self-imposed dietary shifts to support environmental sustainability are a present reality for many, and also foreseen to grow (Willits-Smith et al., 2020).

Diets are distributed along a spectrum with the strict vegan (excludes all foods of animal origin) on one end, followed by vegetarians (excludes meat and meat-derived foods),

pescatarians (plant-based diet with inclusion of seafood), flexitarians (plant-based diet and consumption of any meat in limited amounts), and the omnivorous (no meat restrictions) in the opposite extremity (Figure 1; based on Hargreaves et al., 2023). In that spectrum, the seafood market and especially the growing aquaculture industry are strategically positioned to cater for the majority of dietary groups (Figure 1). However, consumers' choices about what to purchase and eat has the potential to alter production trends and markets (O'Malley et al., 2023).

From 2014, the number of seafood alternatives or analogs has increased in availability more than 5 times in some national markets (Boukid et al., 2022). Seafood analogs mimic the structure, texture, and sensorial characteristics of meat usually with a complete plant-based composition, in order to satisfy consumers that enjoy seafood but have concerns about the environmental consequences of this industry (Kazir and Livney, 2021). Moreover, cell-based seafood grown from conventional animals, although in primary development stages, could potentially come to 'popular' adoption in the future, provided constraints such as high price, accessibility, and demand in lieu of conventional seafood are surpassed (Halpern et al., 2021). Nonetheless, it is believed that seafood alternatives may in part lessen the demand for conventional seafood, shaped by society's demand (Marwaha et al., 2022).

Despite the increasing dietary transformation, the aquaculture industry has seen demand grow in recent years and contributes to 49% of total aquatic production (FAO, 2022). Increases in seafood demand come with consumers' questions about the production process, traceability, and environmental considerations. Indeed, if aquaculture is not sustainably planned it can have negative effects, such as genetic introduction in nature from escapes (Soto et al., 2023), overestimation of an area's carrying capacity (Comeau et al., 2023), habitat degradation (Elwin et al., 2019), and potential food safety related to antiquated legislation (Rosa et al., 2020). Issues such as the lack of transparency and environmental responsibility in food industries can lead to rejection from many consumers whose first choice has seemingly shifted from personal preference to a more collective view based on environmental ethics.

Within this scenario, industry-led focus on increased sustainability of aquaculture and adoption of local environmental actions can concomitantly support sustainable goals for global health while also meeting the expectation of environmentally-conscious consumers. This is important because there has been little market-based justification to increase the aquatic farm-gate sustainability as a whole. I focus on the two most science-based triggers for dietary choices, namely health and environmental sustainability, to discuss the shifts, the knowledge behind shift triggers, and finally, suggested actions to connect seafood farming production with the goals of sustainable diets and consumers.

## The spread: dietary shifts for sustainability are an affluent economies trend?

Dietary shifts resulting from the preoccupation with the environmental impacts of meat production are not reserved to affluent nations. In fact, meat consumption is usually associated with wealth and richer economies (Forestell, 2018). Increases in the consumption of meat (and fish) can occur as a result of economic expansion and urbanization, as in some non-Western countries such as India, China, and Myanmar, although Southeast Asia and Sub-Saharan Africa have a high number of vegetarians (e.g., Bangladesh and India; Rao et al., 2018; Fukase and Martin, 2020; Zhang et al., 2022). In Vietnam and Kenya, meat supply in recent years has increased, together with the countries' diet-related environmental footprint (Heller et al., 2020). On the other hand, in Indonesia, considerable dietary shifts did not occur with urbanization and the traditional diet high in cereals and plants still predominates both in urban and rural areas, showing that urbanization-triggered dietary shift does not always hold true (Colozza and Avendano, 2019). Notwithstanding, assessments of dietary changes and country-specific data are limited for the majority of non-Western countries (Heller et al., 2020), but those countries are also expected to partake in the healthy-environmental-diet transition due to increasing diet-related disease incidence (Tilman and Clark, 2014).

Although earlier in 2016 a report concluded only Brazil, Germany, Qatar, and Sweden included environmental sustainability in their food-based dietary guidelines (FBDG, Gonzalez Fischer and Garnett, 2016), the number of countries reporting the links of diet with human health and environmental sustainability is increasing. Presently, the FBDGs from 37 nations, including 3 low-income or lower-middle-income countries, mention environmental sustainability. Within the FBDGs two types of documents (scientific documents and consumer summary) the two most common dietary guiding principles were

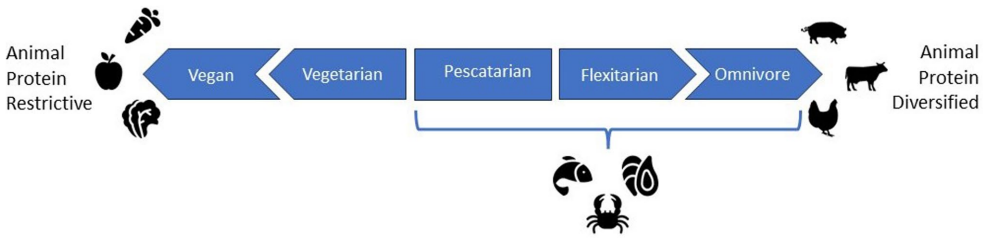


FIGURE 1
The food spectrum of main diets. Towards the right, diets are more inclusive, progressively adding more, and diversified, animal-origin foods and proteins, but also including items from the left (vegetables, fish, etc.); towards the left, the diets are more selective, progressively restricting selected animal-origin foods and proteins. Note that the seafood market caters for the majority of main diets, as highlighted. (*Disclaimer: this graph has been designed using images from Freepik available at Flaticon.com*).

plant-based and animal-based foods, which shows the increased relevance of plant-based food in contemporary diets (James-Martin et al., 2022). Worldwide many FBDGs are advocating for increased adoption of plant-based diets instead of animal-origin protein and reporting "environmental sustainability" as the key factor for this suggested transition (James-Martin et al., 2022).

Additionally, nations that culturally represent more carnivorous diets, with a variety of meat in national dishes, are among the top nations with vegetarian citizens, such as Germany (6%) and Brazil (3%), behind for example India with 25% and the United Kingdom with 7% (Statista, 2023), and Mexico (2%), which has a high number of more non-conventional vegan dieters (Vanderlee et al., 2022). Public interest in limiting consumption of meat is increasing (Forestell, 2018), as eating less of any kind of meat and less of all kinds of meat was expressed as goals by more than 40 and 30%, respectively, of interviewees in Australia, Canada, Mexico, United States, and United Kingdom (Vanderlee et al., 2022).

While in its current status, the dimension of the seafood market and increased demand portrays a safe economic environment and a considerable displacement of conventional seafood by its seafood alternatives is unlikely, acknowledging the dimension of the aforementioned dietary shifts now will allow the seafood industry to better stand for a resilient business and loyal customers.

## The triggers: dietary shifts as truly informed decisions

The actual number of people restricting their diets to meat-free or plant-based is still considerably low worldwide, but expanding. Therefore, it is important and expected that consumers are provided with enough information to make sound decisions concerning diets that are more sustainable. That choice should be based on well-informed background knowledge grounded in up-to-date science. Nonetheless, a brief review shows there is not strong evidence against keeping seafood in one's menu based on human health and the environment.

### Health

The latest EAT-Lancet report suggests the inclusion of seafood in what is considered a sustainable diet (Mbow et al., 2019), a concept that combines health and environmental concerns (Springmann et al., 2018), and is defined as that with low environmental impacts, which contribute to food and nutrition security and to a healthy life, and is environmentally-friendly, culturally acceptable, accessible, nutritive, and safe (FAO, 2010). In a review of diet health effects and the metabolic syndrome (e.g.: low good cholesterol (HDL), impaired glucose metabolism, high blood pressure and inflammatory biomarkers, risks of heart disease and diabetes), Thomas et al. (2023) concluded that the vegan diet has unsatisfactory levels of HDL, even though it lowers body weight and inflammatory markers; with better prospects of vegetarian and pescatarian diets concerning improved effects of inflammation, and cardiovascular issues. O'Malley et al. (2023) found better health eating indexes for pescatarians, followed by vegetarians, vegans, and omnivores. Pescatarians also had lower risk of heart disease and overall good reduction in risks for all-cause diseases exceeding the performance of vegetarian diets (Tilman and Clark, 2014). Substitutions of conventional seafood by alternatives can be significantly less healthy as some types of products have lower quality protein, more salt, and lack micronutrients when compared to their conventional counterparts, although most alternatives had no additives or preservatives, but nutrition and health effect studies of seafood alternatives are still limited (Boukid et al., 2022).

### Environment

Studies have shown discrepancies between the environmental outcomes from production of beef, poultry and pork, to the production of aquatic species and agricultural crops (Tilman and Clark, 2014; Hilborn et al., 2018; Froehlich et al., 2018a; Halpern et al., 2019). Still, there are a number of different environmental stressors that remain unaddressed and should be considered in the analysis of sustainable food systems (Halpern et al., 2019). In spite of that, vegan, vegetarian, pescatarian diets are connected to positive environmental effects in many assessments, in this order. However, in a case study in Europe, none of the main diets (vegetarian, pescatarian, and omnivorous) were sufficient to meet the climate IPCC goals of carbon emissions (Masino et al., 2023). At present, seafood alternatives have very low chances of contributing to fisheries recovery and coastal sustainability, while aquaculture presents an immediate and realistic alternative to fisheries pressure (Halpern et al., 2021). Projections resulting from a switch in diets from omnivorous to pescatarian led to reductions of greenhouse gas emissions in food production (GHGEs; Tilman and Clark, 2014), in some cases better than vegetarian scenarios (Masino et al., 2023). Fundamentally, following energy-balanced dietary guidelines (flexitarian, pescatarian, vegetarian, and vegan diets) are more effective in reducing environmental pressures than following approaches that only consider the environment (cut of consumption of animal products at constant calorie intake; Springmann et al., 2018).

Similar to previously discussed, a recent study analyzing the balance between the health and environmental benefits of the four diet types concluded that vegan and vegetarian choices may bring nutritional deficiencies for groups of people that need special nutritional attention, categorized as children, pregnant and lactating women, and the elderly (Moreno et al., 2022). Additionally, for low-income countries, adhering to global policies of sustainability of diets can be challenging due to the widespread prevalence of malnutrition, and possible ecological burdens associated with providing adequate nutrition for the population. Modeled shifts to plant-forward diet scenarios increased global GHGEs and water footprints when adequate caloric intake was accounted for, mainly due to undernourished countries such as India, Pakistan, and Indonesia (Kim et al., 2020). A less restrictive flexitarian diet, while not as environmentally-friendly as the vegan, considerably reduces environmental impacts compared to Western diets and satisfies the recommended nutritional needs (Moreno et al., 2022). A modest inclusion of low-food chain animals (e.g., forage fish, bivalves) in diets is also compared to vegan diets in terms of environmental footprint across different countries (Kim et al., 2020).

Therefore, not including seafood in a diet for health and environmental reasons alone is still debatable, especially when target cultured species make use of completely different farming systems and

environments, and can require (e.g., finfish, crustaceans) or not require (extractive species; e.g. bivalves, seaweed) the use of feed. In fact, the GHGEs from aquaculture were estimated to be 10% of the agriculture emissions, mainly associated with the production of raw feed materials, and secondarily with transportation (Mbow et al., 2019). Nevertheless, production of the global aquaculture industry has a lot of room for sustainability improvement (for details see Jiang et al., 2022).

## The actions: the need for innovative practices and informative efforts in aquaculture

### Literature review

A literature review from the Scopus database at the time of writing, shows the relationship between the most common diet terms ("vegan", "vegetarian", "pescatarian", "flexitarian" within title, abstract, keywords) and topics of sustainability, demonstrating that they are directly intertwined with the methods of food production systems across the historical usage in research (Figure 2, Research Timeline) of the aforementioned terms. The percentage of environmental research has remained stable in recent years within the long-standing "vegetarian" (3%) and "vegan" (4%) diets, but is more relevant in modern diets ("flexitarian", 5%; and "pescatarian" adoption, 9%; Figure 2, Subject Type A, B, C, D). Keywords from the publications can indirectly inform the relevance of the sustainability research within each diet. Sustainability terms, such as "sustainability" and "climate change," were associated with the vegan, pescatarian and flexitarian diets. But more specific terms such as "greenhouse effect/gases," "environmental impact," "sustainable development," and "carbon dioxide," were only related with the two more modern diets (Figure 2, Keywords). Accordingly, although pescatarian-focused research is relatively more concentrated within the environmental field, flexitarian-focused research recurrently mentions more sustainable terms, but both diets seem to be aligned with research of environmental context.

### In practice

The aquaculture industry has increasingly adopted more sustainable practices in production and processing, for instance, with more efficient feed rates, and increased production of extractive species, with a "sustainability criteria progressively shaping the direction of the industry" (Naylor et al., 2021). However, the overwhelming negative perception of aquaculture by the public

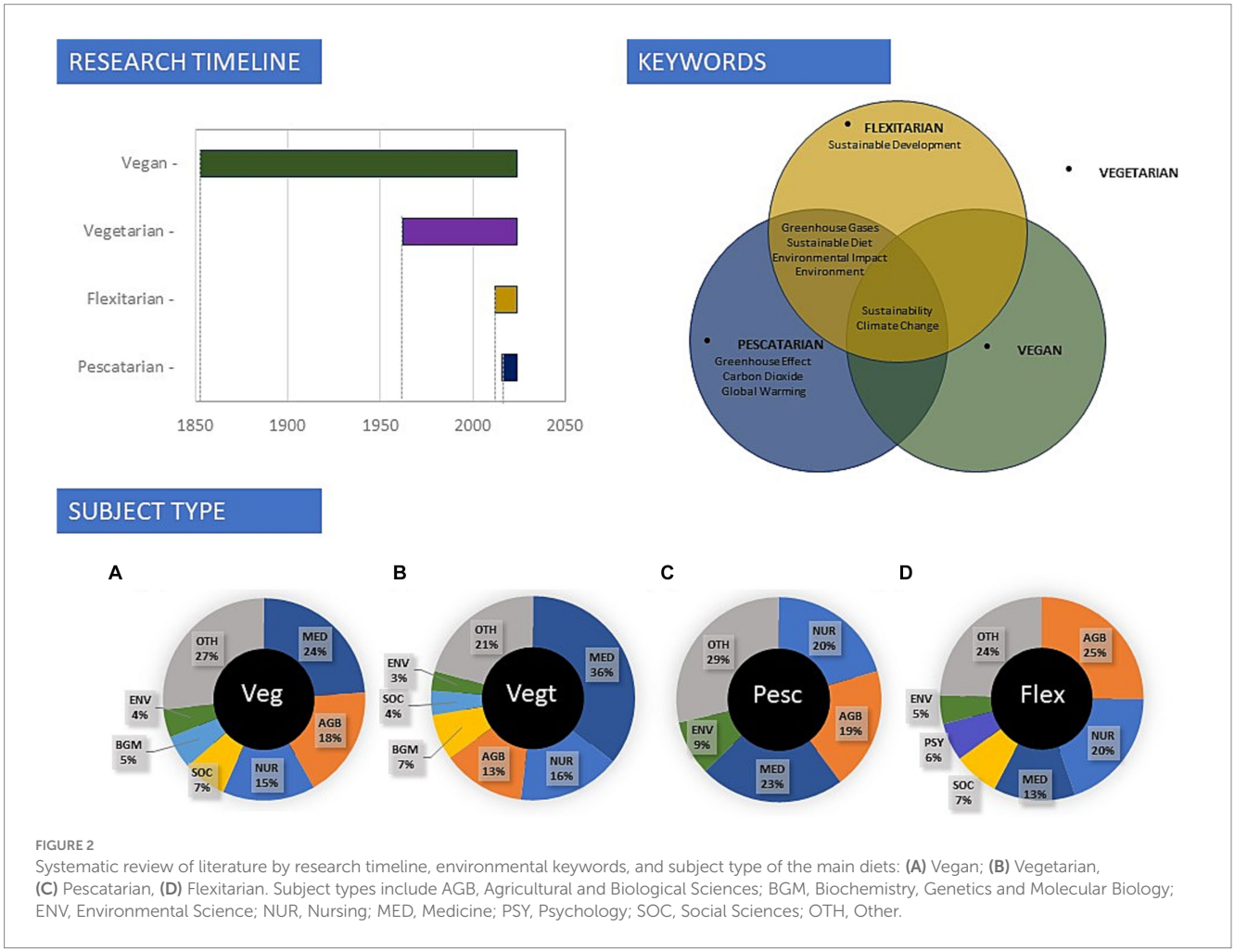


FIGURE 2
Systematic review of literature by research timeline, environmental keywords, and subject type of the main diets: **(A)** Vegan; **(B)** Vegetarian, **(C)** Pescatarian, **(D)** Flexitarian. Subject types include AGB, Agricultural and Biological Sciences; BGM, Biochemistry, Genetics and Molecular Biology; ENV, Environmental Science; NUR, Nursing; MED, Medicine; PSY, Psychology; SOC, Social Sciences; OTH, Other.

persists together with a lack of ocean literacy (Froehlich et al., 2017; Petereit et al., 2022; Zajicek et al., 2023), often resulting in a lack of social acceptability, public opposition to the industry expansion (license to operate), and possible behavioral changes in consumers' food choices. This reiterates the ongoing need for sustainable aquaculture practices and proactive efforts to counter misinformation through substantially improved communication.

Surprisingly, the public view and increasing sustainable measures in the farming process and marketability are not cited as main preoccupations among global aquaculture farmers, who often consider risks such as possible diseases, price fluctuation, and environmental disasters as the main pressing issues related to their business (Alam and Guttormsen, 2019; Cantillo and Van Caillie, 2023). However, sustainability topics have not been completely ignored as some larger operations have acknowledged the significance of seafood certifications, the promotion of sustainable practices for market differentiation, recognition of carbon credits, and assessment of sustainability in food-chain models as opportunities for the sector; with agreement among farmers about the necessity to promote the sustainable production methods to consumers (Schrobback et al., 2021).

The persistent problem is that positive attributes of seafood for health and aquaculture's contributions to environmental sustainability remain largely unrecognized by the majority of consumers who lack knowledge about the seafood farming process, and positive effects of some types of production on the environment (e.g., ecosystem services, wise use of natural resources; Jonell et al., 2016; Shaughnessy et al., 2023). Nevertheless, "familiarity with the topic" and "opinion malleability" about the aquaculture effects were positively related to more acceptance of aquaculture products after consumers were provided with brief related information (Shaughnessy et al., 2023). This is because consumers are mostly unaware of aquaculture practices but interestingly, they are willing to pay more for a farmed product after being educated about its production and possible related ecosystem services (Bolduc et al., 2023). Even food literacy is only moderate among consumers of all dietary classes (including pescatarians and other seafood eaters). However, flexitarians had higher general nutrition knowledge, while critical nutrition knowledge was higher among vegans (Groufh-Jacobsen et al., 2023).

While recent research did not find a positive correlation between scientific knowledge and seafood consumer purchases (Petereit et al., 2022), it did not specifically look into the consumers' knowledge about the farming methods and production stages. Rather, the study associates mistrust in certification labels and vegetarian self-identification with non-purchase of seafood despite the awareness of its health benefits, reinforcing the fact that environmental concerns may overshadow health aspects. It also highlights customer-driven demand for transparency and traceability, which was additionally cited to play a role in direct purchase decisions.

Like any other economic activity, aquaculture has some environmental trade-offs. Unsurprisingly, if more diets shift towards being seafood-heavy, such as the pescatarian diet, there will be increased necessity of actions such as more production of extractive species, waste reduction, and use of alternative feed sources for fed-species (e.g., finfish, crustacea) to attend demand sustainably (Froehlich et al., 2018b). Well-known practices at the farm level can substantially increase the farming industry's sustainability. For instance, the choice of species and alternative aquaculture designs, such as integrated multi trophic aquaculture (IMTA), co-culture of native species, restorative aquaculture, and regenerative aquaculture are some practical examples of how the industry can further exercise sustainability (see Mizuta et al., 2023 for details). Some species and farming designs will more effectively contribute to positive environmental effects than others, but several types of farms and different cultured species can provide multiple ecosystem services (Gentry et al., 2020; Theuerkauf et al., 2021; Barret et al., 2022). Mediterranean farmers assessed about their perceptions of environmentally-friendly practices in aquaculture stated an active implementation of environmental protection measures (organic farming, reduced stocking density), especially in marine areas more than in freshwater farming. However, they were not in complete agreement with the use of alternative eco-friendly farming practices, expressing skepticism over the use of alternative feeds, and ignoring other environmentally-friendly management approach such as co-culture and IMTA systems due to the lack of specialized knowledge for experimentation and full implementation (Perdikaris et al., 2016).

In the post-harvest supply chain, effectively showcasing sustainable practices implemented in the production should be a fundamental aspect of any aquaculture operation. Accredited sustainable certifications and seafood guides (e.g., Seafood Watch; Aquaculture Stewardship Council) can not only attest to sustainable practices but usually positively correlate with purchases by consumers who are concerned with the environmental impacts of seafood production (Jonell et al., 2016). In addition to certification schemes, there is room for alternate governance approaches to ensure effective sustainability outcomes in seafood production and therefore clearer understanding of outcomes (Rector et al., 2023). Lastly, relational food supply chains, where direct networks between farmers and consumers are implemented through geographic proximity and feedback loops, can help small-scale farmers showcase their sustainability practices (Stoll et al., 2019).

Since there is some evidence that the public trusts more scientists and farmers themselves as sources of the latest available information on aquaculture production and products (Shaughnessy et al., 2023), the role of collaborations between the research institutions and the industry is primordial to guide new industry actions, then inform the general public. The role of governmental institutions and NGOs are also fundamental and complementary, especially in advisory, financing, capacity building, promotion of best practices and cross-learning (Paterlow et al., 2023). Ultimately, all actors involved in aquaculture should jointly facilitate frequent improvement of sustainably-forward actions, monitoring and assessment of results, updated information dissemination, and reevaluation of management and production design, in a repeating pattern to ensure positive environmental outcomes and information delivery.

## Final thoughts

Moving towards sustainable aquaculture food systems is imperative. Although dietary preference is an absolute personal choice, there is a call for a stronger recognition that aquaculture can have its importance minimized in part by the consumers' uninformed

perceptions and related dietary lifestyle changes, despite the contribution that aquaculture can make in providing nutritive protein, and food security, through relatively more sustainable production systems, particularly with extractive species.

Aware of this trend, the aquaculture industry should prioritize the implementation of practices supported by science to reflect the public environmental concerns. As aquaculture progresses towards more sustainable approaches, it is necessary to follow those actions with updated information dissemination focused also on the end user, who are after all the central point of the business. The aquaculture industry already demonstrates, but should increase, two commitments: effective green-action and attested information dissemination not only to cater to "consumers" who demand healthier, safe, nutritious foods, but also to "consumer activists", who desire to incorporate in their daily lives considerations for a healthy planet and would like to make more deliberate diet decisions.

## Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: the data of this study are derived from resources available in Scopus database. Dataset can be made available upon request.

## Author contributions

DM: Writing – original draft, Writing – review & editing.

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## Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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