http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 43(2), 138-144 (2026)

Su Ürünleri Dergisi (2026)
DOI: 10.12714/egejfas.43.2.06

RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Strategic decoupling and structural resilience in global seafood trade: Lessons from the COVID-19 pandemic (2020–2024)

Küresel deniz ürünleri ticaretinde stratejik ayrışma ve yapısal dayanıklılık: COVID-19 pandemisinden çıkarılan dersler (2020–2024)

Mehmet Fatih Can[1] • Metin Yazıcı[1]* • Azize Ahsen Can[2]

[1]Faculty of Marine Sciences and Technology, İskenderun Technical University, 31200, İskenderun, Hatay, Türkiye
[2]Faculty of Business Administration, Bilkent University, 06800, Ankara, Türkiye

*Corresponding author: metin.yazici@iste.edu.tr

Received date: 19.01.2026 Accepted date: 24.03.2026

How to cite this paper:
Can, M.F., Yazıcı, M., & Can, A.A. (2026). Strategic decoupling and structural resilience in global seafood trade: Lessons from the COVID-19 pandemic (2020–2024). *Ege Journal of Fisheries and Aquatic Sciences, 43*(2), 138-144. https://doi.org/10.12714/egejfas.43.2.06

Abstract: The COVID-19 pandemic induced unprecedented disruptions in global food supply chains, with the seafood sector experiencing unique volatility due to its high perishability and complex logistics. This study investigates the resilience of global seafood trade by analyzing import data obtained from the International Trade Centre (ITC) Trade Map database across nine product categories defined under the Harmonized System (HS 0301–0309) from 2020 to 2024. Utilizing a dual-metric approach of market volatility (Coefficient of Variation) and recovery velocity (CAGR), we identify a significant structural shift in market composition. Results indicate that while high-value, logistics-sensitive categories like crustaceans (HS 0306) exhibited moderate volatility, processed categories such as fish fillets (HS 0304) demonstrated superior resilience, consolidating a permanent market share above 22%. Furthermore, a distinct "V-shaped" recovery in fresh/chilled products (HS 0302) by 2024 suggests a full restoration of global logistics networks, yet under a new equilibrium where shelf-stable and value-added products play a more critical role in food security. These findings highlight the need to promote processing capacity, value addition, and product diversification strategies to enhance the resilience of global seafood trade against future systemic shocks. This research provides strategic insights for policymakers and industry stakeholders, emphasizing that future industry resilience depends on value-addition and the diversification of product forms to mitigate systemic shocks.

Keywords: Seafood trade, COVID-19 pandemic, supply chain resilience, market volatility, food security, structural shift

Öz: COVID-19 pandemisi, küresel gıda tedarik zincirlerinde eşi benzeri görülmemiş aksamalara yol açmış; deniz ürünleri sektörü ise yüksek bozulabilirlik ve karmaşık lojistik yapısı nedeniyle bu süreçte özgün bir oynaklık sergilemiştir. Bu çalışma, 2020–2024 döneminde, Uluslararası Ticaret Merkezi (ITC) Trade Map veri tabanından elde edilen ithalat verilerini, Uyumlaştırılmış Sistem (HS 0301–0309) kapsamında tanımlanan dokuz ürün kategorisi üzerinden analiz ederek küresel deniz ürünleri ticaretinin dayanıklılığını incelemektedir. Piyasa Oynaklığı (Varyasyon Katsayısı) ve Toparlanma Hızı (Bileşik Yıllık Büyüme Oranı, CAGR) olmak üzere iki göstergeden oluşan ikili bir analitik yaklaşım kullanılarak, piyasa bileşiminde belirgin bir yapısal dönüşüm tespit edilmiştir. Bulgular, kabuklular (HS 0306) gibi yüksek katma değerli ve lojistik açıdan hassas ürün gruplarının orta düzeyde oynaklık sergilediğini; buna karşılık balık filetoları (HS 0304) gibi işlenmiş ürün kategorilerinin üstün bir dayanıklılık göstererek %22'nin üzerinde kalıcı bir pazar payını koruduğunu göstermektedir. Ayrıca, taze/soğutulmuş ürünlerde (HS 0302) 2024 yılı itibarıyla gözlenen belirgin "V-şekilli" toparlanma, küresel lojistik ağlarının büyük ölçüde yeniden işlerlik kazandığına işaret etmekte; ancak bu toparlanmanın, raf ömrü uzun ve katma değerli ürünlerin gıda güvenliğinde daha kritik bir rol üstlendiği yeni bir denge altında gerçekleştiğini göstermektedir. Bu bulgular, gelecekteki sistemik şoklara karşı küresel deniz ürünleri ticaretinin dayanıklılığını artırmak amacıyla işleme kapasitesinin geliştirilmesini, katma değer oluşturulmasını ve ürün çeşitlendirme stratejilerinin desteklenmesini hedefleyen politikaların gerekliliğini ortaya koymaktadır. Bu çalışma, sistemik şokların etkilerinin azaltılmasında katma değer yaratılmasının ve ürün formlarının çeşitlendirilmesinin belirleyici olduğuna vurgu yaparak, politika yapıcılar ve sektör paydaşları için stratejik çıkarımlar sunmaktadır.

Anahtar kelimeler: Deniz ürünleri ticareti, COVID-19 pandemisi, tedarik zinciri dayanıklılığı, piyasa dalgalanması, gıda güvenliği, yapısal dönüşüm

INTRODUCTION

The global seafood sector represents a critical pillar of the international food system, providing at least 20% of the animal protein intake for approximately 3.3 billion people and supporting tens of millions of livelihoods worldwide (FAO, 2022; Alam et al., 2022). Beyond its nutritional contribution, aquatic foods are increasingly framed as essential elements of sustainable food-system transformation (Hasselberg et al., 2024; Vogliano et al., 2024).

The COVID-19 pandemic has functioned as an unprecedented "stress test," exposing vulnerabilities across seafood production, logistics, labor, trade and consumption (Bassett et al., 2021; Hobbs, 2021; Rathod et al., 2022). Lockdowns and transport restrictions disrupted harvesting, processing, and international trade, leading to sharp and uneven market declines (Found et al., 2024; Alam et al., 2022).

In the European Union, closure of the HoReCa (Hotel, Restaurant, Catering) sector produced one of the sharpest disruptions, particularly affecting fresh and live high-value products (Seixas et al., 2024; Bassett et al., 2021). Conversely, frozen, filleted, canned, and shelf-stable commodities displayed greater resilience (Wei et al., 2023; Asche et al., 2022; Huang et al., 2025). A similar pattern emerged in Türkiye, an important regional producer and exporter, where early trade-impact assessments indicate contractions in live/fresh exports and simultaneous increases in preserved and value-added products (Can et al., 2020; Mol et al., 2024; Saygı et al., 2025).

Recent scholarship argues that these changes mark the emergence of a post-pandemic "fillet-centric" seafood trade model, where standardized processed categories drive resilience and market dominance (Wei et al., 2023; Domínguez-Martínez et al., 2025). This shift has been strengthened by rapid digitalization and the expansion of direct-to-consumer distribution models (Stoll et al., 2021; Belhadi et al., 2024).

Simultaneously, global food and seafood systems appear to be transitioning from "just-in-time" to "just-in-case" procurement logics, prioritizing redundancy and risk spreading (Hobbs, 2021; Found et al., 2024). New structural pressures—including climate policy uncertainty, geopolitical trade fragmentation, and sustainability expectations—further reshape supply-chain governance (Brahmana and Aslam, 2025; Hasselberg et al., 2024).

Despite extensive qualitative analysis, there remains a gap in longitudinal quantification of these structural shifts (Asche et al., 2022; Seixas et al., 2024). Addressing this, the present study analyses a five-year dataset (2020–2024) to assess the resilience of nine seafood product groups defined under the Harmonized System (HS 0301–0309), the consolidation of fillet-based trade systems, and geopolitical restructuring among key demand centers (Wei et al., 2023; Domínguez-Martínez et al., 2025; FAO, 2022).

MATERIALS AND METHODS

Data collection and scope

All trade data used in this study were retrieved from the International Trade Centre (ITC) Trade Map database. The dataset encompasses global import values over the five-year period from 2020 to 2024, capturing the pre-pandemic phase (prior to the World Health Organization's declaration of COVID-19 as a pandemic on 12 March 2020), the peak-pandemic period, and the subsequent post-pandemic stabilization phase. The scope of the research includes all nine primary product categories under the Harmonized System (HS) Chapter 03, as detailed in Table 1.

Table 1. Classification and description of analyzed seafood product groups (HS Codes)

Product group (HS code)	Content summary / Description
HS 0301 (Live fish)	Live fish, including ornamental and food-grade species.
HS 0302 (Fish, fresh/chilled)	Fresh or chilled fish, excluding fish fillets and other fish meat of heading.
HS 0303 (Frozen fish)	Frozen fish, excluding fish fillets and other fish meat of heading.
HS 0304 (Fish fillets & meat)	Fish fillets and other fish meat, whether fresh, chilled, or frozen.
HS 0305 (Dried/salted/smoked)	Fish, fit for human consumption, dried, salted, or smoked.
HS 0306 (Crustaceans)	Crustaceans (e.g., shrimp, lobster, crabs), in shell or not.
HS 0307 (Molluscs)	Molluscs (e.g., oysters, mussels, squid, octopus), in shell or not.
HS 0308 (Aquatic invertebrates)	Aquatic invertebrates other than crustaceans and molluscs.
HS 0309 (Flours/meals/pellets)	Flours, meals, and pellets of fish and invertebrates, fit for human consumption.

Quantitative metrics and formulas

The resilience and recovery trajectories of each product category were evaluated using two primary statistical indicators: market volatility, measured by the Coefficient of Variation (CV), and recovery velocity, measured by the Compound Annual Growth Rate (CAGR). Together, these metrics capture both the magnitude of trade instability during the pandemic shock and the capacity for post-shock recovery.

Market volatility: coefficient of variation (CV)

To quantify the relative stability of each seafood category, the Coefficient of Variation (CV) was employed. This metric allows for a standardized comparison of volatility across groups with different market sizes. Following Sokal and Rohlf (1995), the CV is calculated as the ratio of the standard deviation (σ) to the mean (μ):

$$CV = \frac{\sigma}{\mu}$$

Growth dynamics: compound annual growth rate (CAGR)

The Compound Annual Growth Rate (CAGR) was utilized to determine the geometric progression of import values from 2020 to 2024. This approach provides a smoothed annual growth rate, mitigating the impact of year-over-year fluctuations (Damodaran, 2012; Fabozzi and Peterson Drake, 2009). The CAGR is defined as:

$$CAGR = \left[\left(\frac{V_{2024}}{V_{2020}}\right)^{\frac{1}{4}} - 1\right] \times 100$$

Where $V_{2024}$is the final value, $V_{2020}$is the initial value, and 4 represents the duration of the period in years.

Geopolitical selection criteria

To assess geopolitical shifts in demand, the study focused on three major global seafood importing entities: the United States of America, China, and the European Union — represented by its leading importers, Spain, France, and Italy — which emerged as key actors based on the preliminary data analysis. Collectively, these entities account for over 60% of global seafood trade value, thereby providing a representative sample of global demand dynamics.

Data processing and visual analytics

The numerical analysis and data cleaning were performed using the Python (v3.9) programming environment, utilizing the Pandas library for statistical computation.

RESULTS

Market resilience and dynamic risk analysis

The global seafood trade exhibited a heterogeneous growth and volatility profile during the 2020–2024 period. Sectoral resilience was assessed using the Coefficient of Variation (CV) and Compound Annual Growth Rate (CAGR), presented through the "Resilience Matrix" illustrated in Figure 1.

The analysis indicates that the Fresh/Chilled Fish (HS 0302) category was among the fastest-recovering segments, exhibiting a CAGR of 8.13%. The Live Fish (HS 0301) category similarly demonstrated a high recovery trajectory with a CAGR of 8.08%; however, its volatility, reflected in a CV of 17.4%, underscores its continued logistical vulnerability. In contrast, Fish Fillets (HS 0304) emerge as the "resilient star" of the market, combining low volatility (CV=0.10) with strong growth (CAGR=5.54), positioning this segment as the most structurally stable contributor to post-pandemic market performance (Figure 1).

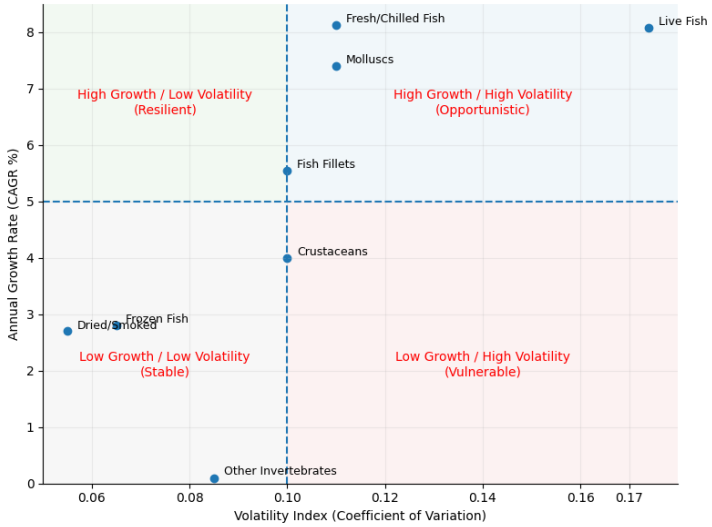

Figure 1. Seafood resilience matrix: comparative analysis of volatility and growth (2020–2024)

Structural transformation and volume trends in market composition

The total value of the global seafood market, encompassing nine primary product groups, rose from USD 113.6 billion in 2020 to a peak of USD 148.7 billion in 2022, before stabilizing at USD 138.9 billion by 2024. These value changes, along with the shifting distribution of product-level market shares, are visualized using the dual-axis model presented in Figure 2.

Structurally, Crustaceans (HS 0306) and Fish Fillets (HS 0304) continued to serve as the dominant market pillars, jointly accounting for approximately 45% of total market value in 2024. A five-year breakdown of market share distribution across product categories is provided in Table 2.

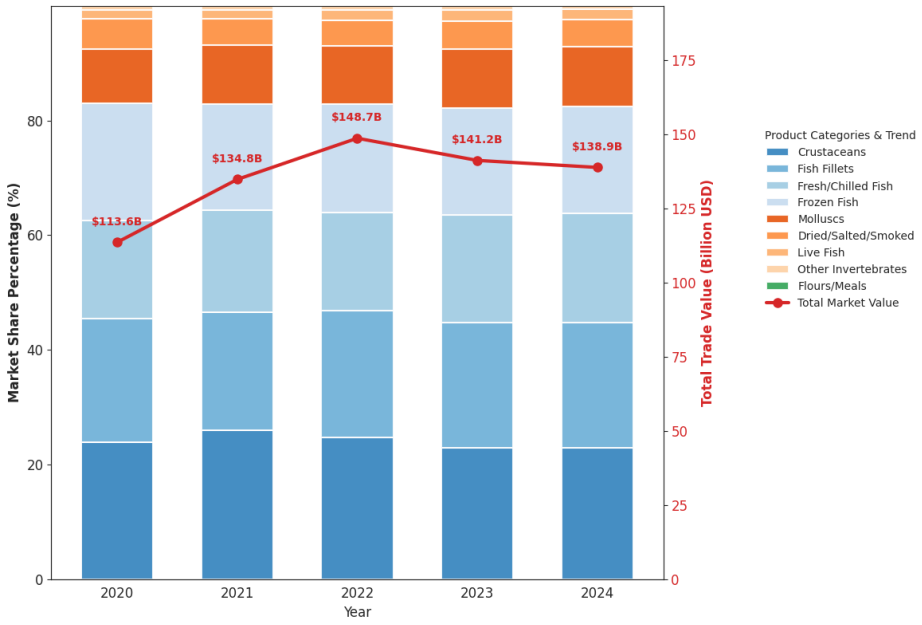

Figure 2. Structural transformation of global seafood trade value and composition

Table 2. Structural evolution of global seafood market shares (2020–2024, %)

Product Category	2020 (%)	2021 (%)	2022 (%)	2023 (%)	2024 (%)	Trend
Crustaceans (0306)	23.91	25.97	24.76	22.95	22.90	Stable-Down
Fish Fillets (0304)	21.58	20.65	22.09	21.88	21.91	Consolidated
Fresh/Chilled (0302)	17.05	17.74	17.12	18.76	19.07	Growing
Frozen Fish (0303)	20.43	18.50	18.88	18.60	18.62	Stable-Low
Molluscs (0307)	9.52	10.33	10.23	10.26	10.37	Resilient
Live Fish (0301)	1.59	1.58	1.77	02.02	1.78	Recovery

It should be noted that the Trend classification presented in Table 2 is based on the joint interpretation of growth performance (CAGR) and market volatility (CV), rather than on growth rates alone. Although HS 0301 (Live Fish) and HS 0302 (Fresh/Chilled Fish) exhibit similar CAGR values (8.08% and 8.13%, respectively), their classification differs due to contrasting volatility levels. HS 0302 demonstrates a more stable growth trajectory and is therefore categorized as "Growing," whereas HS 0301, despite its high total growth (+36.5%), exhibits significantly higher volatility (CV=17.4%), reflecting its continued exposure to logistical and market disruptions. For this reason, HS 0301 is classified under "Recovery," indicating a rebound pattern under persistent structural fragility.

Product-level disaggregated trade trends

The sector's trajectory toward 2024 reflects the distinct logistical and demand-side dynamics inherent to each product group. As illustrated in the panel charts in Figure 3, Molluscs (HS 0307) and Fresh Fish (HS 0302) exhibited the most stable upward trajectories in the post-pandemic period. Absolute annual trade values for each product category are presented in Table 3 in billion-USD format.

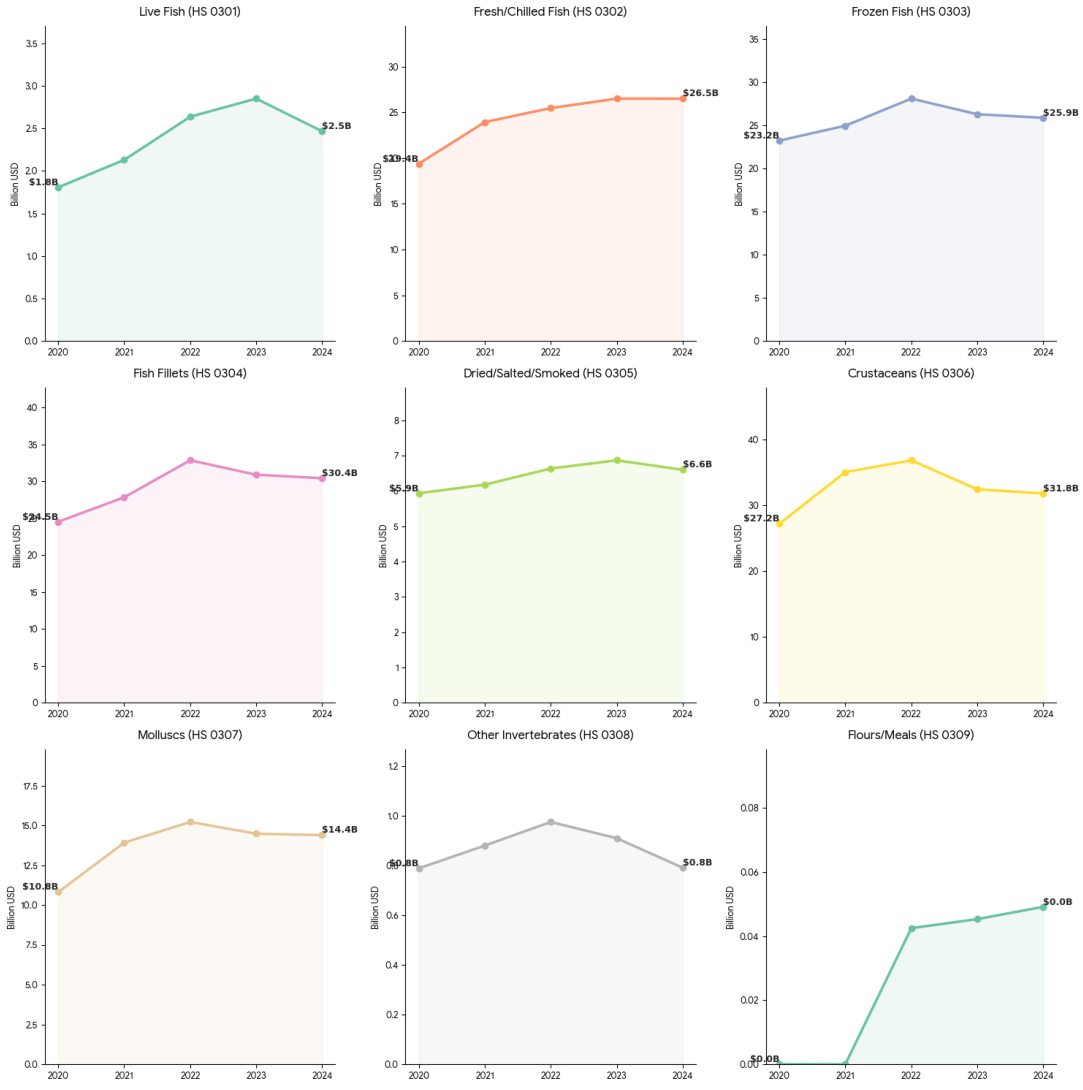

Figure 3. Disaggregated trade value trends for 9 product categories (HS 0301-0309)

Table 3. Annual trade values by product category (2020–2024, Billion USD)

Category	2020	2021	2022	2023	2024	Total growth (%)
Crustaceans	27.18	35.02	36.82	32.42	31.80	+17.0%
Fish Fillets	24.53	27.84	32.86	30.90	30.43	+24.1%
Fresh/Chilled	19.37	23.92	25.46	26.49	26.49	+36.8%
Frozen Fish	23.21	24.94	28.08	26.27	25.86	+11.4%
Live Fish	1.81	2.13	2.64	2.85	2.47	+36.5%

Geopolitical shifts in demand and import performance

A comparative assessment of the major demand engines — the United States, China, and the European Union (selected member states) — is presented in Figure 4. China emerged as the leading growth market, recording a CAGR of 9.66%, whereas the EU demonstrated the highest degree of stability, as reflected by its CV value of 0.09, identifying it as the least volatile importing region. A summary of regional performance metrics is provided in Table 4.

Table 4. Comparative performance metrics for leading importers (2020–2024)

Region	2020 value (B)	2024 value (B)	CAGR (%)	Volatility (CV)	Resilience posture
USA	17.53	21.02	4.64	0.12	Demand-Driven
China	12.37	17.89	9.66	0.17	Strategic Expansion
EU (Selected)	15.57	19.79	6.18	0.09	Stability-Oriented

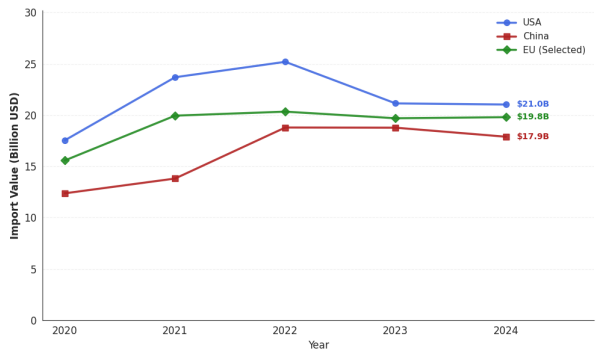

Figure 4. Geopolitical shifts in seafood demand: USA, China, and EU

DISCUSSION

The longitudinal analysis of global seafood trade from 2020 to 2024 reveals not merely a post-pandemic recovery but a deeper structural reconfiguration of the sector. These findings support the view that COVID-19 functioned as a directional shock shaping long-term industry evolution rather than a temporary disturbance (Hobbs, 2021; Bassett et al., 2021; Found et al., 2024). In this context, the results corroborate the concept of *emerging resilience*, defined as the capacity of seafood supply chains to adapt through diversification, redundancy, and digital transformation (Stoll et al., 2021; Belhadi et al., 2024). Importantly, however, this resilience is unevenly distributed across product categories and geographic regions.

The pronounced shift toward processed commodities—particularly fish fillets (HS 0304), which exhibited sustained compound annual growth rates and comparatively low volatility—aligns with evidence from European Union markets, where standardized processed formats served as primary buffers against pandemic-related disruptions (Seixas et al., 2024; Asche et al., 2022). The "pivot toward shelf-stable formats," initially observed during 2020–2021, appears to have consolidated into a permanent structural feature of the post-pandemic seafood economy. This transformation is consistent with projections indicating that digital packaging solutions, harmonized certification systems, and the expansion of e-commerce reduce cross-border transaction costs and enhance coordination efficiency (Wei et al., 2023; Belhadi et al., 2024). Nevertheless, these advances primarily mitigate informational and organizational frictions and do not eliminate exposure to physical cost shocks.

Geopolitical asymmetries in trade growth—most notably China's markedly stronger expansion in seafood imports and processing volumes relative to the more moderate growth observed in the United States—reflect a broader reorientation of global seafood trade gravity toward Asia. Prior studies identify China as a strategic processing and re-export hub, where diversification strategies and economies of scale generate systemic resilience (Alam et al., 2022). By 2024, this role appears further reinforced by a widespread shift from "just-in-time" to "just-in-case" procurement strategies, as firms adapt to persistent logistics fragility, port congestion, and volatility in maritime freight markets (Hobbs, 2021; Found et al., 2024).

At the same time, the rapid rebound of the fresh and chilled seafood category (HS 0302) during 2023–2024 indicates that, although frozen and processed products functioned as effective shock absorbers, premium fresh seafood continues to play a central role in value generation. This recovery does not contradict the structural shift toward shelf-stable formats; rather, it suggests the emergence of a dual market structure in the post-pandemic seafood economy. In this configuration, processed and frozen products provide volume stability and risk mitigation, while fresh seafood remains disproportionately sensitive to energy prices, transportation constraints, and emissions-related costs (Mol et al., 2024; Rathod et al., 2022). These dynamics reinforce recent arguments that the "new normal" in seafood markets is characterized by digitally monitored yet climate-exposed trade systems, where geopolitical positioning, energy risk management, and adaptive procurement policies jointly shape competitiveness (Wei et al., 2023; Hasselberg et al., 2024).

The observed macro-level trade patterns complement earlier production-focused assessments of the COVID-19 shock in aquaculture systems. While studies such as Ahmed

and Azra (2022) document disruptions in aquaculture inputs, production practices, and value addition at farm and value-chain levels, the present analysis extends this literature by demonstrating how upstream constraints translated into longer-term structural adjustments in global seafood trade networks.

Beyond market and logistical considerations, the structural shift toward processed and shelf-stable seafood products also carries indirect implications for aquaculture production systems. Increased reliance on standardized and value-added formats is typically associated with longer production cycles and higher biomass retention, thereby elevating the importance of fish health management, biosecurity, and stress mitigation as prerequisites for supply continuity. From this perspective, biological resilience at the farm level can be understood as a complementary foundation underpinning the structural resilience observed in post-pandemic global seafood trade.

CONCLUSION

This study demonstrates that the global seafood trade has undergone a structural transformation rather than a short-term recovery between 2020 and 2024. The evidence points to three defining shifts: the consolidation of processed and standardized product forms, the geopolitical relocation of processing and trade influence toward Asia, and the institutionalization of digital systems across supply chains.

Processed products — particularly fillets — now form the most resilient and strategically advantageous segment of the market, offering consistent growth and reduced vulnerability to logistics and energy-related disruptions. Meanwhile, fresh and chilled products continue to serve as the primary drivers of value, albeit with heightened exposure to cost and climate volatility, making them strategically dependent on well-developed cold-chain systems and energy-efficient distribution.

Geopolitically, the distribution of market power is shifting: China has strengthened its role as a global processing hub, while Western markets are transitioning toward premium-quality, sustainability-oriented consumption patterns. This indicates a new trade configuration in which value does not solely depend on production volume but increasingly on technological capacity, energy resilience and market positioning.

Digital transformation has evolved from an emergency adaptation mechanism to a structural requirement. Supply chains increasingly rely on traceability technologies, standardized certification, and real-time monitoring, reshaping how competitiveness is maintained and how risk is mitigated under conditions of uncertainty.

While the present findings are derived from trade data, they highlight the critical role of biological and production resilience in aquaculture systems in shaping the overall stability of seafood supply chains, underscoring the importance of integrating bio-economic approaches in future research. Overall, the findings suggest that the seafood sector is entering a new era defined by resilience, standardization, digital maturity and geopolitical diversification. As global markets move toward 2030, the key determinants of success will include energy transition alignment, climate-adaptive logistics, and the strategic ability of countries and firms to balance value, risk and sustainability across evolving trade networks.

ACKNOWLEDGEMENTS AND FUNDING

The authors declare that this research did not receive any specific funding from public, commercial, or non-profit funding bodies.

AUTHOR CONTRIBUTIONS

Mehmet Fatih Can: Conceptualization, methodology, formal analysis, data curation, writing – original draft, visualization, Mehmet Fatih Can, Metin Yazıcı, Azize Ahsen Can: Writing – review & editing. All authors have read and approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest or competing interests.

ETHICAL APPROVAL

No specific ethical approval was required for this study.

DECLARATION OF AI USE

The authors declare the use of Open AI's Chat GPT-5 for assistance in English language editing and grammar correction during manuscript preparation. The content and scientific interpretations are solely the responsibility of the authors.

DATA AVAILABILITY

The data used in this study are publicly available and were obtained from the International Trade Centre's Trade Map database (https://www.trademap.org/Index.aspx).

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