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The Threshold Effect of Overfishing on Global Fishery Outputs: International Evidence from a Sustainable Fishery Perspective

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Abstract: Using global fishery outputs from 62 countries during the period 2001–2020, this study applies the threshold panel data model of Hansen (2000) to empirically explore the nonlinear relations between the number of fishing vessels, fishers, and fishery production, with distinct overfishing stocks (overfishing) and fish caught by trawling or dredging techniques (trawling) as the threshold variables. Our findings show that the levels of fishery outputs could be increased by different combinations of primary factors, such as the number of fishing vessels and fishers. More specifically, when the number of fishing vessels and fishermen operating in countries with a high ratio of overfishing (overfishing > 4.4456) increased, their fishery outputs significantly increased as compared with countries with a low percentage of overfishing. As overfishing activities increase, they can result in significant shortages and imbalances of fishery resources, directly influencing fish biomass, biodiversity, and sustainability of fisheries, as well as making destructive fishing practices worse for marine ecosystems. Countries with a relatively high proportion of trawler net usage (trawling > 4.5516) would have significantly lower fishery outputs, as more fishing vessels are invested in them, compared with countries with a low proportion of trawling net use. This implies that trawler net usage is a non-sustainable fishing technique and harms fishery resources. The policy implications of this study indicate that taxing overfished species and implementing trawling regulations could significantly improve species richness and site-based abundance, thus helping to sustain fishery outputs.

Keywords: global fishery outputs; sustainable development goals (SDGs); overfishing; trawling and dredging

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1. Introduction

The production of food from the ocean has a crucial position in supply, provides resources, and ensures food security for our society [1,2], but human population growth has contributed to a decline in biologically sustainable fishing stocks, approximately from over 89% to under 70% in recent years. Specifically, marine fish consumption increased by more than 60% between 1990 and 2018 [3]. Regardless of the scenario, the global primary production and presence of top predators are anticipated to decline significantly [4,5]. An ensemble of ecosystem models predicts for a long period from 2006 to 2100 claim that fish biomass will decrease by an average of 17% under high emission conditions [6]. The effects of overfishing vary significantly between species and geographical areas [7,8].

The term overfishing refers to situations where insufficient fishing and defaunation result in declining fish populations [9]. High overfishing damages community structures and fish sizes, resulting from the selective harvesting of species and the bycatching of other species, along with habitat modification as a result of changes in biomass, species composition, and size structure [10–12]. The FAO [13] reported that more than 85% of global fish stocks are either overfished or fully exploited, and overfishing or lower biomass limits are responsible for the 40% reduction in Europe's fish stocks [14,15]. Several fisheries in the European Union (EU) have a current fleet size and capacity that exceed sustainable levels by two to three times [16].

Overfishing reduces the adaptability of fish stocks and aquatic resources to climate change [15,17]. Moreover, overfishing is directly related to a variety of detrimental fishing practices, including illegal, unreported and unregulated (IUU) fishing, bycatching, and harmful subsidies [18,19]. Overfishing could occur if harmful fishing techniques such as bottom trawling are continued, as this destroys the ocean's seafloor and affects both some species that are specifically targeted and those that are not [20,21]. Furthermore, harmful subsidies lead to overfishing by supporting fleets with excessive numbers, resources, and technology [18,22].

Therefore, the research objective of this study is to empirically investigate the threshold impacts of overfishing stocks (SDG14 overfishing) and fish caught by trawling or dredging techniques (SDG14 trawling) on global fishing outputs, by controlling for the number of fishing vessels, number of fishers, and national income.

2. Materials and Methods

Once fisheries are unable to keep up with the growing demand for fishery products, aquaculture has expanded and now exceeds fish production [13]. The more prominent role of aquaculture has resulted in more fish production, competition between wild and aquaculture fish production, and increased trade. The high demand for seafood products inadvertently creates opportunities for fishermen to overfish, due to the high economic value associated with maximizing the discounted value of present and future net benefits [23]. Overall, overfishing actions can cause a significant reduction in fishery outputs.

2.1. Study Area

In this study, we used a global fishing output database, covering 2001 to 2020, derived from the fisheries' statistical yearbooks published by the FAO website https://www.fao.org/fishery/en/statistics, accessed on 17 August 2022. We have also collected data on sustainable development goal scores (SDG14) from the website https://dashboards.sdgindex.org/rankings, accessed on 17 August 2022. Finally, we obtained the GDP annual growth rate and poverty rate as control variables provided by the World Bank statistics (available website: https://databank.worldbank.org/source/world-development-indicators, accessed on 17 August 2022). We then aggregated the data to enable us to analyze the more specific target levels, which include the global fishery outputs and the goals of SDG14 (fish grabbed from overfishing or tumbled stocks and fish grabbed by trawling or dredging).

This study primarily focuses on the global fishery outputs from 2001 to 2020 using the data from 62 countries (see Figure 1). Overall, the fishery outputs caught in Asia fluctuated from 1,504,057 to 50,100,000 (tons of live weight). As shown in Figure 1, we found that Chinese fishermen caught an average of 50,100,000 tons of live fish each year, followed by Indonesia (8,326,168 tons), India (4,424,787 tons), and Vietnam (2,658,570 tons). There is an interesting difference between the fishery production in the Americas and Asia during the period 2001–2020. Asia region grabbed almost as much freshwater and anadromous fish, ranging from 18,314,993 to 47,260,766 tons live weight, in comparison to the Americas region's 1,250,587 and 1,516,139 tons live weight.

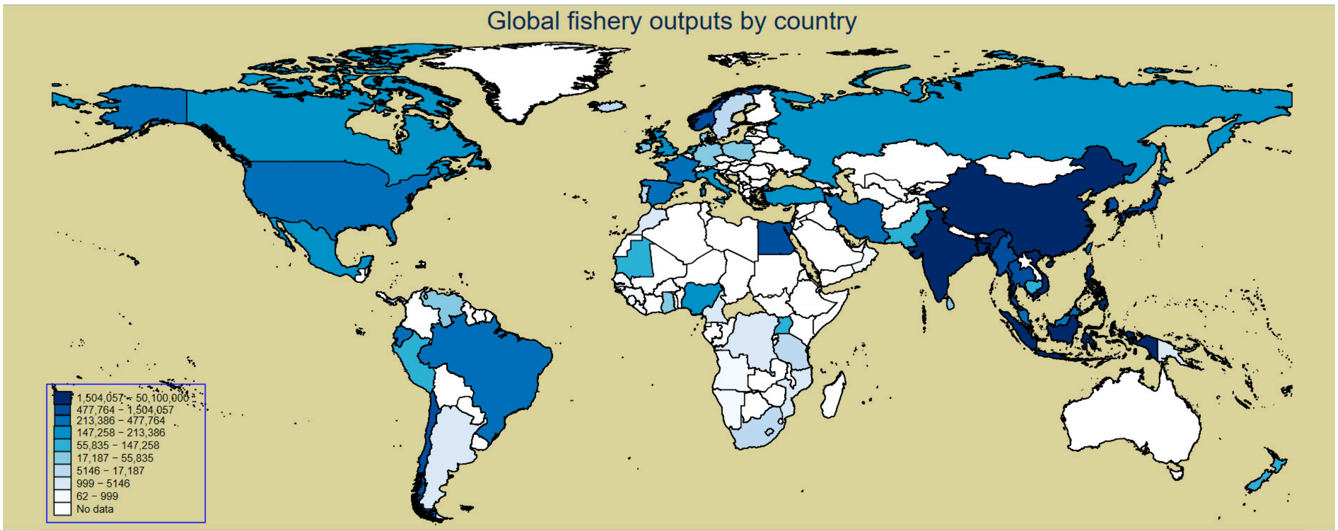


Figure 1. Geographical locations of the global fishery outputs from 2001 to 2020.

Overfishing's impact on global fishery outputs. Assemblage overfishing, a common phenomenon, refers to fishing down marine (or aquatic) food webs [10,24]. The phenomenon of "fishing down" is when fisheries target large fish in an ecosystem, and their abundance is reduced relative to that of smaller fish [25]. Additionally, overfishing has become increasingly evident, causing indirect changes in habitat structure and processes [26–29]. Overfishing is a longer-term issue that results from an imbalance between the resources used for harvesting (the resulting current level of output) and the resources required (corresponding output) for harvesting at an "optimal" scale. Overcapacity and excessive fishing inputs have been a leading concern around the world since the recent debate about managing fishing capacity began. According to the Code of Conduct for Responsible Fisheries proposed by The Food and Agriculture Organization (FAO), excessive fishing capacity threatens fisheries' resources and their ability to sustainably provide catches as well as benefits to fishers and consumers. However, the FAO reported in Article 6.3 section and cautioned that "Nations could take steps to avoid overfishing and excess fishing capacity and implement management measures to ensure that fishing effort is adequate for the productive capacity of fishery resources and their long-term consumption."

Overfishing and habitat destruction have depleted one-third of the world's fish stocks [17]. Overexploitation has had long-term effects on marine ecosystems and poses severe risks to ocean health, such as biodiversity, food security, and coastal livelihoods and economies [17,30–32]. Overfishing frequently has significant environmental impacts [33,34], and has even been recognized as a driver of shifts in ecosystem regimes [35]. Overfishing directly impacts fish biomass, biodiversity, and the sustainability of fisheries, as well as exacerbating destructive fishing approaches' impact on marine ecosystems (e.g., bottom trawlers). As a result of illegal, unreported, or unregulated fishing, overfishing is usually performed with high-impact fishing gear, such as bottom trawlers, which negatively affect the benthic substrate [36]. Overfishing activities over time can lead to a significant scarcity of aquaculture resources. Evidence shows that up to 70% of fish stocks in European waters are currently overfished, or at their lower biomass limits [37]. While some encouraging actions are being taken, several regulations have been implemented to control overexploitation. The buyback of fishing vessels, or the setting of tax rates by species in proportion to the extent of overexploitation, have been performed [38]. The level of tax related to overfished species should be determined by how much effort is being focused on each species—more severely overfished species will incur a higher rate [38]. Taxing overexploited fish species would increase the price for consumers, resulting in a reduction in fish consumption. In response to lower demand, processors and wholesalers offer fishers lower prices upon landing, resulting in lower fishing efforts.

Trawling or dredging. Trawling accounts for approximately 25% of the global capture of fishing [39], and it is increasingly being considered as an unsustainable fishing technique [40–42]. It has two impacts on benthic ecosystems. First, by disrupting epibenthic sediments, fishing gear causes losses of habitat complexity and the resuspension of sediments into the water column [43–45], leading to lower organic matter contents in sediments [46]. The second consequence of trawling is that it disrupts the structure of benthic communities by selectively removing large-bodied species, which results in small r-selected species dominating in benthic communities [21]. The management of fisheries and the preservation of aquatic life have long been affected by bottom trawling (BOT) [47,48]. BOT results in bycatching and the discarding of non-target species, such as endangered or protected species [49,50]. From 1950 to 2014, BOT accounted for 23% of landed marine catches and 60% of fisheries' discards globally [51]. However, Roda et al. [52] showed that this percentage has dropped to 46% in recent years (2010–2014). Since most of its effects are felt in coastal waterways, pressure is being placed on those ecosystems [53,54]. A few countries prohibit bottom trawling because of the harm it causes to marine life [55,56]. For example, since 2013, Chinese policymakers have undertaken several steps to safeguard marine fisheries and tighten regulations on bottom trawling, such as prohibiting the authorization and production of bottom trawlers [56]. Additionally, the authorities of the Hong Kong Special Administrative Region also banned trawling to aid in the recovery of fishery resources and associated benthic ecosystems. Their findings indicate that a trawl ban can significantly improve species richness and site-based abundance, which implies that it is an efficient approach for conserving biodiversity in tropical coastal seas [20].

Sustainable development goal 14 (SDG14). The primary target of SDG14 is to protect and utilize the oceans, seas, and marine ecosystems sustainably. To accomplish this, all maritime stakeholders must participate in the various aspects of SDG14. Most efforts have been directed towards the first four targets: sustainable management, marine pollution, sustainable fishing, and ocean acidification. It has been more difficult to eliminate fishery subsidies, as stated in target 14.6.

SDG—Sustainable management. Sustainable development goal (SDG) 14.2 aspires to effectively manage and safeguard marine and coastal habitats, increase their resilience, reduce harmful effects, and attain productive and healthy oceans (United Nations, 2018). Management plans that consider all human activities are necessary if we are to achieve this aim. However, all these steps are administered by different entities, leading to extremely fragmented ocean management [57–59]. The project manager of marine resources is a critical contributor to ocean management. Most of these resources are managed via a specific species approach, which neglects interspecies interactions, habitat influences, and ecosystem dynamics, leading to overfishing, habitat damage, and changes in the aquatic community [60]. Integrating ecosystem-based management (EBM) into fisheries management is one efficient way to achieve comprehensive management [61–63]. Executing ecosystem-based management is a long-term goal that requires much more effort be applied at different levels. The fishing industry could provide a valuable input by participating in EBM discussions and decision making [64]. Bycatch and other effects of fishing represent additional avenues of engaging with this goal. Generally, the involvement in environmental management of fishing enterprises will be critical to restoring marine ecology and reducing overfishing [65]. While EBM has several benefits, implementation has been relatively slow due, primarily, to training challenges [62].

SDG—Subsidies. Subsidies aggravate the problem of overexploitation and fleet overcapacity. They are monetary payments made by the government to private recipients in the fishing industry [66,67]. According to Sumaila et al. [68] and Da-Rocha et al. [69], subsidized overcapacities can harm the marine environment in the long run, and directly impact its productivity. Sustainable Development Goal 14.6 aims to prevent subsidies that significantly exacerbate these problems (United Nations 2018). However, eliminating the use of harmful subsidies in the fishing industry is made complicated by political and social concerns. Thus, if the management institution is to address this issue, it may require the careful consideration of financing for income supplements and transitional measures to minimize immediate losses [70]. Research by Da-Rocha, García-Cutrín, Prellezo and Sempere [69] demonstrated that cutting subsidies leads to lower societal costs than anticipated. Diversifying and governing days at sea are two methods for reducing the number of vessels, a common strategy that the government could use to reduce harms and prevent overfishing [71].

2.2. Threshold Panel Data Model

The study examined the impact of overfishing on global fishery outputs, and the dependent variable is the fishing outputs. In order to reduce heteroscedasticity, logarithmic processing was performed, which referred to prior study [72]. Fishery outputs can be used to reflect the intensity of fishery resources' development, and will be affected by many factors, such as the number of fishers, and sustainable development goal scores for ocean-related issues (SDG14).

The independent variables in this study are calculated by the logarithm of the number of fishing vessels (LogNFV) and the number of fishers (LogNF). In terms of control variables, we have utilized a dummy income variable (high income, lower-middle income, and upper-middle income). These data were obtained from the fisheries' statistical yearbooks published by the FAO with time series data from 2001 to 2020. All variables are reported clearly in Appendix A.

Remarkably, the threshold panel data model put forward by Hansen (2000) was combined with the Log of SDG14 overfishing (the proportion of grabbed from overfishing or tumbled stocks (% of total catch)) and SDG14 trawling (the proportion of fish grabbed by trawling or dredging) as the threshold variables to evaluate the function parameters of fishery outputs. The single-regime threshold panel data model for cross-country panel data is represented in Equation (1), where k_i stands for the threshold variables, λ_1* stands for the optimal threshold value, and f (.)is an indicator function. If the relationship in (.) is true, then f(.) equals 1; otherwise, f(.) is 0. The parameters α_1, α_2, γ_1, γ_2, θ_1, θ_2, ξ_1, and ξ_2 are to be estimated:

$$\begin{aligned} LogGFO_{i,t} = & \left[\alpha_1 (Technological\ progress)_{i,t} + \gamma_1 LogNFV_{i,t} + \theta_1 LogNF_{i,t} + \xi_1 Income_{i,t}\right] \times f(k_{i,t} \leq \lambda_1^*) \\ & + \left[\alpha_2 (Technological\ progress)_{i,t} + \gamma_2 LogNFV_{i,t} + \theta_2 LogNF_{i,t} + \xi_2 Income_{i,t}\right] \times f(k_{i,t} > \lambda_1^*) \end{aligned} \tag{1}$$

where *Log* refers to the logarithm; GFO_i is global fishing outputs as a proxy for fishing production performance (tons of live weight); $(Technological\ progress)_{i,t}$ presents time trend, represented as by the years between 2001 and 2020; $NFV_{i,t}$ is the global number of fishing vessels (motorized vessels propelled by engines); $NF_{i,t}$ is the global number of fishers; and $Income_i$ is categorized into distinct levels (HIC = high income, LMIC = lower-middle income, UMIC = upper-middle income).

In this equation (Equation (1)), the threshold parameter λ (SDG14 overfishing and SDG14 trawling) as sample-splitting (or threshold) variables. The impact of technological progress, the number of fishing vessels, fishers, and income level on global fishery outputs will be α_1 and α_2 for countries with a low or high regime, respectively. It is obvious that under the hypothesis, $\alpha_1 = \alpha_2$; $\gamma_1 = \gamma_2$; $\theta_1 = \theta_2$; and $\xi_1 = \xi_2$ in the model.

Our estimate procedure compares the threshold model in Equation (1) to the linearity null hypothesis, H_0: $\alpha_1 = \alpha_2$. The fact that the threshold parameter λ was not detected when the null hypothesis was kept caused a non-standard inference concern. Both Wald and Lagrange multiplier tests failed to follow their typical chi-square patterns [73,74]. Instead, conclusions are reached by generating Wald or Lagrange multiplier (score) statistics for each possible value of λ, and then making inferences based on the sum of the Wald or Lagrange multiplier potential λ_s. This statistic's limiting distribution is non-standard and relies on several model-specific nuisance factors. Instead of tabulations, inferences are produced using a bootstrap model whose validity and features have been demonstrated by

Hansen (1996). The slope parameters' estimations come naturally as $\beta(\lambda)$ and $\gamma(\lambda)$ after an estimate of λ has been acquired (as the minimizer of the residual sum of squares computed over all possible values of λ). The failure of the test demonstrates that the threshold effect exists. Secondly, for robustness, we also follow the procedure proposed by Hansen [74] for investigating the possibility of multiple threshold effects. We posit the detailed hypotheses: the single threshold corresponds to the linear and single-threshold models (hypotheses H_0 and H_a). In contrast, the double threshold equals single and double-threshold models (including hypothesis H_0 and H_a), respectively, and so forth.

3. Results

3.1. Preliminary Analysis

The global fishery outputs in tons of live weight are reported in Table 1. Panel A of Table 1 demonstrates the mean value of variables by year regarding the global fishery outputs, the global number of fishing vessels, the number of fishers, SDG14 overfishing, SDG14 trawling, GDP growth rate, and poverty ratio for the years 2001 to 2020. Specifically, the average global fishery outputs ranged from 716,897 to 1,941,143 (tons of live weight). Connecting Panel C, we found that China's highest average global fishing output was 50,100,000 (tons live weight), followed by Indonesia, India, and Vietnam with the mean value of 8,326,168, 4,424,787, and 2,658,570 (tons live weight), correspondingly. All remaining variables are shown in the details of Panel A and C. Panel B demonstrates the mean value of all variables by region, the global fishing outputs in the Southeast Asia region have a mean value of 5,535,225 tons live weight, which is the highest region in comparison to Africa and Oceania regions of 29,353 and 2829 (tons live weight), respectively. Interestingly, the percentage of overfishing in Oceania, the Middle East, North Africa, and South East Asia is higher than in the other regions. At the same time, Oceania, Europe, and Central Asia have the most remarkable rate of fishing by trawling and dredging. Other variables are clearly described in Panel B of Table 1.

We present the groups of species of the global fishery outputs by continent from 2001 to 2020 (see Appendix B: Groups of species from FAO by continent), including Aquatic Animals NEI, Aquatic Plants, Crustaceans, Demersal Marine Fish, Freshwater and Diadromous Fish, Marine Fish NEI, Molluscs excluding Cephalopods, and Pelagic Marine Fish. Specifically, fishery outputs in Asia almost related to Freshwater and Diadromous Fish (ranging from 18,314,993 to 47,260,766, tons live weight), in comparison to the Americas region (between 1,250,587 and 1,516,139, tons live weight) in grabbing Freshwater and Diadromous Fish. Furthermore, Demersal Marine Fish species range from 100,753 to 453,845 in Africa where European region shows fishery outputs between 116,212 and 205,799 (tons live weight). In terms of Aquatic Plants species and Molluscs without Cephalopods, the fishery outputs in Asia range from 10,781,141 to 34,916,316 (tons live weight) and between 9,219,565 and 16,158,709 (tons live weight).

Moreover, the species groups of worldwide fishing outputs by income classification based on the World Bank are shown in Appendix **??**. It found that lower-middle-income nations yield more freshwater and diadromous fish, ranging from 4,675,907 to 22,060,390 tons, compared to upper-middle-income nations' 14,044,467 to 27,839,930 tons. According to Mollusks excluding Cephalopods, the value of upper-middle-income nations (8,350,940–15,231,576 tons) shows substantially higher than that of low-income countries (60,000–62,420 tons). Similarly, the outputs of Aquatic Plants in upper-middle-income countries present the highest in other countries, ranging from 8,423,150 to 21,075,219 tons.

Figure 2a shows that the nonlinear effects of overfishing (SDG14 overfishing) negatively impact global fishing outputs. Similarly, the results of trawling net (SDG14 trawling) negatively impact fishing outputs, which indicates that overfishing and trawling activities can lead to a decrease in the global fishery outputs (see Figure 2b).

Table 1. The descriptive statistic variables by year, region, and country from 2001 to 2020.

Panel A: The mean value of variables by year.

Year	Observations	Global Fishery Outputs	Overfishing	Trawling	NFV (Number of Fishing Vessels)	NF (Number of Fishers)	GDP Growth Rate	Poverty Rate
2001	62	716,897	74.33	80.18	39,653	527,542	47.67	18.07
2002	62	766,203	74.29	79.81	40,292	528,153	48.79	18.02
2003	62	812,125	73.33	80.74	40,124	537,879	49.20	17.68
2004	62	881,533	71.94	80.77	38,535	557,982	50.77	17.23
2005	62	935,467	70.31	81.88	40,880	541,681	50.18	16.30
2006	62	995,938	67.93	80.98	40,030	564,652	50.87	16.02
2007	62	1,048,080	66.17	81.49	40,641	530,685	50.71	15.61
2008	62	1,109,958	65.92	81.28	41,920	543,191	48.49	14.92
2009	62	1,168,047	65.57	81.42	42,913	558,465	45.21	14.16
2010	62	1,234,563	65.22	81.57	41,097	571,106	49.76	13.17
2011	62	1,292,839	65.76	82.09	41,275	577,512	49.25	12.87
2012	62	1,397,460	65.65	82.94	40,776	563,890	48.73	11.30
2013	62	1,505,387	64.97	81.64	38,495	561,428	48.67	11.13
2014	62	1,578,629	65.77	82.22	42,363	579,659	48.72	11.31
2015	62	1,647,904	68.16	83.04	41,624	579,574	48.25	10.64
2016	62	1,715,094	69.02	82.19	41,379	576,410	48.06	10.96
2017	62	1,778,825	69.82	81.87	41,824	577,776	48.60	10.49
2018	62	1,836,535	70.07	81.75	40,657	576,055	48.20	9.75
2019	62	1,897,315	69.24	81.69	39,214	572,649	47.70	10.15
2020	62	1,941,143	68.92	81.77	39,721	559,559	41.49	9.92

Panel B: The mean value of variables by world region.

Region	Observations	Global Fishery Outputs	Overfishing	Trawling	NFV (Number of Fishing Vessels)	NF (Number of Fishers)	GDP Growth Rate	Poverty Rate
Africa	280	29,353	73.61	87.90	9150	191,327	50.92	39.15
Europe and Central Asia	40	74,129	60.04	99.91	1004	85,834	50.13	5.42
South East Asia	260	5,535,225	81.11	72.97	120,028	2,199,454	51.71	12.15
Latin America and the Caribbean (LAC)	140	120,545	64.97	95.24	13,525	157,712	48.77	6.83
The Middle East and North Africa (MENA)	80	297,380	81.30	72.63	29,505	211,453	49.49	4.08
OECD	420	326,311	56.35	76.95	29,423	49,295	44.28	0.68
Oceania	20	2829	86.03	105.00	514	248,000	50.09	40.90

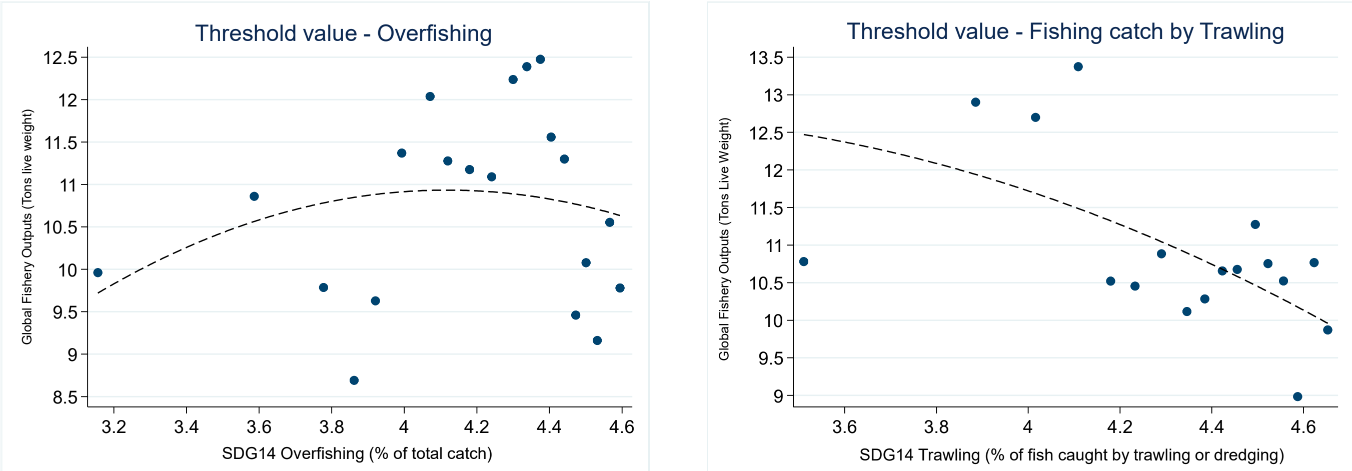
Note: GFO is the global fishing outputs (tons live weight); Overfishing is the fish caught from overexploited or collapsed stocks (% of the total catch); Trawling is the fish caught by trawling or dredging (% of fish caught by trawling); NFV is the global number of fishing vessels (number of motorized vessels propelled by engines); NF is the global number of fishers (number); GDP growth rate is the gross domestic product annual growth rate (annual %); Poverty rate is the proportion of poverty headcount at national poverty lines (% of population). All variables are reported clearly in Appendix A.

Table 1. *Cont.*

Panel C: The mean values of variables by country.

Country	Observations	Global Fishery Outputs	Over-Fishing	Trawling	NFV (Number of Fishing Vessels)	NF (Number of Fishers)	GDP Growth Rate	Poverty Rate	Country	Observations.	Global Fishery Outputs	Over-Fishing	Trawling	NFV (Number of Fishing Vessels)	NF (Number of Fishers)	GDP Growth Rate	Poverty Rate
Angola	20	553	88.52	68.65	2467	84,676	51.17	17.08	Mozambique	20	1735	83.66	105.00	1096	224,555	52.49	70.95
Argentina	20	2727	58.79	53.11	1490	19,887	47.61	2.34	Myanmar	20	748,168	85.57	54.63	15,090	2,909,199	55.47	3.47
Bangladesh	20	1,525,550	98.27	90.67	27,206	1,500,570	52.07	19.35	Namibia	20	426	75.59	68.42	218	19,906	49.27	22.60
Belize	20	5147	44.69	104.95	586	3074	48.08	5.51	Netherlands	20	55,836	48.22	75.79	840	2526	47.24	0.10
Brazil	20	419,035	81.80	91.02	31,591	848,764	48.09	6.83	New Zealand	20	103,553	51.07	58.47	1420	1847	48.71	0.15
Cambodia	20	110,637	69.95	33.11	56,417	501,575	53.17	33.95	Nigeria	20	184,074	85.72	96.20	36,779	1,122,825	51.40	44.92
Cameroon	20	1235	48.25	96.41	8669	173,570	50.10	25.99	Norway	20	1,034,438	76.66	82.06	6619	12,746	47.54	0.19
Canada	20	169,108	55.17	80.02	19,795	41,199	48.28	0.22	Oman	20	333	97.55	98.19	15,089	42,455	48.88	10.58
Chile	20	962,062	60.00	104.94	13,218	53,883	49.33	2.07	Pakistan	20	127,439	62.93	105.00	13,502	371,384	50.09	13.94
China	20	50,100,000	81.34	55.21	592,406	8,709,106	54.78	12.67	Panama	20	7495	52.61	104.84	8463	36,459	50.95	4.84
Congo, DP	20	3072	43.64	105.00	19,424	275,254	51.28	81.69	Papua New Guinea	20	2829	86.03	105.00	514	248,000	50.09	40.90
Denmark	20	37,026	59.95	66.71	2686	2300	47.21	0.21	Peru	20	73,430	94.71	104.63	4181	85,841	50.17	9.56
Ecuador	20	311,597	64.85	105.00	16,444	63,653	49.00	7.37	Philippines	20	2,149,586	83.65	97.81	183,824	1,927,922	50.86	10.39
Egypt	20	937,234	66.93	52.32	4583	139,358	50.33	2.30	Poland	20	36,934	38.38	66.82	839	4534	49.56	0.60
France	20	213,387	74.21	76.70	5845	15,120	46.93	0.29	Portugal	20	9526	22.01	68.65	7178	17,423	46.38	0.43
Georgia	20	999	49.90	98.97	26	2200	51.05	10.51	Russian Federati	20	147,259	70.18	100.86	1982	169,469	49.21	0.33
Germany	20	40,757	45.51	88.83	1660	2954	47.08	0.01	Senegal	20	534	63.50	87.15	7199	65,597	50.09	36.97
Ghana	20	25,459	63.04	97.16	12,689	234,408	51.99	34.84	Sierra Leone	20	62	98.25	88.09	7442	63,570	51.58	46.98
Guinea	20	315	90.71	82.08	1398	33,406	50.68	34.37	South Africa	20	6294	61.19	80.89	1784	17,748	48.21	22.13
Iceland	20	11,300	50.24	85.72	1731	4633	48.68	0.05	Spain	20	282,526	54.54	59.32	10,357	32,710	47.13	0.81
India	20	4,424,787	94.49	53.51	118,084	7,521,681	52.01	27.82	Sri Lanka	20	17,187	84.94	105.00	25,568	223,890	50.73	5.05
Indonesia	20	8,326,168	81.64	63.16	386,143	3,609,297	50.99	17.52	Sweden	20	10,154	65.13	77.89	1382	1646	48.03	0.48
Iran	20	250,713	70.38	103.38	79,420	552,670	48.96	0.94	Taiwan	20	315,074	81.97	87.39	21,872	243,565	49.68	0.46
Ireland	20	46,859	58.59	91.89	1764	5547	11.22	0.26	Tanzania	20	8592	80.33	105.00	14,149	174,718	52.29	48.82
Italy	20	158,380	37.03	50.60	12,029	30,454	45.85	1.11	Thailand	20	1,107,688	52.24	88.24	18,243	182,686	49.53	2.64
Japan	20	1,140,500	51.09	85.39	266,099	196,766	46.56	0.27	Turkey	20	196,146	56.96	73.39	17,813	62,021	11.84	0.98
Korea, Rep.	20	1,504,057	71.60	67.56	75,352	145,059	49.80	0.22	Uganda	20	70,290	60.96	76.21	6464	80,487	52.31	50.07
Malaysia	20	381,815	79.55	72.61	44,522	120,701	50.43	0.61	United Kingdom	20	199,784	60.65	78.95	6504	12,389	47.26	0.26
Mauritania	20	108,299	87.13	74.29	8328	107,849	49.99	10.68	United States	20	477,764	68.92	82.05	76,140	149,443	47.79	1.00
Mexico	20	162,436	77.41	94.20	88,624	239,990	47.50	4.52	Venezuela	20	24,384	57.30	103.13	31,922	46,306	47.53	11.39
Morocco	20	1240	90.34	36.62	18,929	111,330	49.80	2.52	Vietnam	20	2,658,570	97.92	42.25	57,484	771,327	52.48	10.06

Note: GFO is the global fishing outputs (tons live weight); Overfishing is the fish caught from overexploited or collapsed stocks (% of the total catch); Trawling is the fish caught by trawling or dredging (% of fish caught by trawling); NFV is the global number of fishing vessels (number of motorized vessels propelled by engines); NF is the global number of fishers (number); GDP growth rate is the gross domestic product annual growth rate (annual %); Poverty rate is the proportion of poverty headcount at national poverty lines (% of population). All variables are reported clearly in Appendix A.



(**a**) (**b**)

Figure 2. The nonlinear effects of overfishing (SDG14 overfishing) and fish catch by trawling (SDG14 trawling) on global fishing outputs. (**a**) Threshold value of overfishing; (**b**) threshold value of catching fish by trawling or dredging.

3.2. Summary Descriptive Statistics

Table 2 demonstrates the descriptive statistics about the global fishing outputs, the global number of fishing vessels, the number of fishers, SDG14 overfishing, and SDG14 trawling for the years 2001 to 2020. Specifically, the average global fishing outputs were 10.754 (1,312,997 tons of live weight). We can see that China's highest average global fishing output was 50,100,000 (tons live weight), followed by Indonesia with a mean value of 8,326,168 (tons live weight). The mean global number of fishing vessels was 9.047 (40,671 motorized vessels propelled by engines), while the average global number of fishers was 11.184 (559,292 number of fishers).

Table 2. Descriptive statistics of 62 countries, 2001–2020.

Variables	Measurement Unit	Obs.	Mean	Std Dev.	Minimum	Maximum
Log of global fishing outputs (GFO)	Tons live weight	1240	10.754	3.029	0.693	18.071
Log of global number of fishing vessels (NFV)	Number of motorized vessels propelled by engines	1240	9.047	1.867	3.258	13.453
Log of global number of fishers (NF)	Number of fishers	1240	11.184	2.082	5.298	16.182
Log of SDG14_ overfishing	% of total catch	1240	4.171	0.366	2.194	4.604
Log of SDG14_trawling	% of fish caught by trawling	1240	4.361	0.312	1.609	4.654
High income (HIC)	Dummy variable	1240	0.323	0.468	0.000	1.000
Lower-middle income (LMIC)	Dummy variable	1240	0.339	0.473	0.000	1.000
Upper-middle income (UMIC)	Dummy variable	1240	0.242	0.428	0.000	1.000
Technological progress (Time trend)	Year from 2001–2020	1240	10.5	5.768	1.000	20.000
Log of GDP growth rate	% of annual	1240	3.851	0.319	0.270	4.284
Log of Poverty rate	% of population	1240	2.024	1.192	0.693	4.538

Note: Sample countries include Bangladesh, Sierra Leone, Vietnam, Oman, Peru, India, Guinea, Morocco, Angola, Mauritania, Papua New Guinea, Nigeria, Myanmar, Sri Lanka, Mozambique, Philippines, Taiwan, Brazil, Indonesia, China, Tanzania, Malaysia, Mexico, Norway, Namibia, France, South Korea, Iran, Russian Federation, Cambodia, United States, Egypt, Arab Rep., Sweden, Ecuador, Senegal, Ghana, Pakistan, South Africa, Uganda, United Kingdom, Chile, Denmark, Argentina, Ireland, Venezuela, Turkey, Canada, Spain, Panama, Thailand, Japan, New Zealand, Iceland, Georgia, Cameroon, Netherlands, Germany, Belize, Congo, Dem. Rep., Poland, Italy, and Portugal.

Regarding the sustainable development goals, the average value for SDG14 overfishing in the period 2001 to 2020 was 4.171 (68.619% of total catch). The countries with the highest proportions of total catch fish stocks were Bangladesh and Sierra Leone, with percentages of 98.273 and 98.253, respectively. Furthermore, the average SDG14 trawling was 4.361 (81.566% of fish caught by trawling).

The correlation matrix analysis for the variables employed in the analysis is presented in Table 3. The table demonstrates that the threshold groups (SDG14 overfishing; SDG14 trawling) are negatively associated with global fishery outputs. For example, the correlation between global fishery output and SDG14 overfishing is −0.563, whereas that between global fishery outputs and sustainable development SDG14 trawling is −0.205. In addition, the remaining variables (fishery fleet; global number of fishers; income levels) are positively correlated, whereby the correlation between global fishery outputs and number of fishing vessels is 0.601. The Pearson correlation result between SDG14 overfishing and upper-middle income is negative but insignificant, with a value of −0.0949, while at the same time, SDG14 overfishing is strongly positive with low-middle income of 0.304, GDP growth rate of 0.124, and the poverty rate of 0.296.

Table 3. Pearson correlation results.

Variables	GFO	NFV	NF	SDG14 Overfishing	SDG14 Trawling	HIC	LMIC	UMIC	GDP Growth Rate	Poverty Rate
GFO	1									
NFV	0.601	1								
NF	0.419	0.720	1							
SDG14 Overfishing	−0.563	0.216	0.437	1						
SDG14 Trawling	−0.205	−0.151	−0.822	*−0.138*	1					
HIC	0.139	−0.981	−0.549	−0.363	−0.706	1				
LMIC	0.204	0.193	0.484	0.304	−0.137	−0.494	1			
UMIC	0.336	*−0.538*	*0.201*	*−0.0949*	0.129	−0.390	−0.404	1		
GDP growth rate	−0.305	0.678	0.190	0.124	−0.331	−0.144	0.179	−0.100	1.000	
Poverty rate	−0.409	0.170	0.381	0.296	0.149	−0.620	0.406	−0.476	0.228	1

Note: This table represents the Pearson correlation coefficients of major variables for the full sample of countries. The results of primary Pearson correlations are significant at the 5 percent level or higher, excluding the Pearson correlations in italics. GFO = global fishing outputs; NFV = global number of fishing vessels; NF = global number of fishers; SDG14 Overfishing = sustainable development goals—fish stocks; SDG14 Trawling = sustainable development goals—trawling or dredging; HIC = high income; LMIC = low-middle income; UMIC = upper-middle income, GDP growth rate = the gross domestic product annual growth rate, and Poverty rate = poverty headcount ratio at national poverty lines.

3.3. The Threshold Effect of Overfishing on Global Fishery Outputs

Table 4 displays the results of formula (1) using two distinct SDG14 threshold variables: overfishing and trawling. The bootstrap method with 5000 replications and a 15%-trimmed mean was utilized to estimate the *p*-value, which was used to assess the statistical significance of the threshold value. The bootstrap *p*-values demonstrate that the test of the no-threshold effect can be rejected in all models. Thus, we divided the sample into two distinct regimes. For example, in models 1 and 2, logarithm (NFV) is the global number of fishing vessels (motorized vessels propelled by engines) and logarithm (NF) is the global number of fishers, and the empirical results favor a threshold model. Based on model 1, an overfishing threshold of 4.4456 is estimated, with a 95 percent confidence level of 4.396–4.455. The finding implies that countries categorized as low-SDG14 overfishing clusters (i.e., having a low percentage of fish caught from overexploited groups) are those with threshold values of less than 4.4456, while those classified as high-SDG14 overfishing clusters are those with threshold values greater than 4.4456 (high percentage of fish caught from overexploited groups). Additionally, the threshold value for SDG14 trawling in model 2 has an estimate of 4.5516 and a 95% confidence range from 4.5077 to 4.5523. The finding implies that nations with threshold values below 4.5516 are categorized as belonging to the low-SDG14-trawling clusters (i.e., having a low percentage of fish captured by trawling or dredging), whereas nations with higher values are classified as belonging to the high-SDG14-trawling clusters (with a high rate of fish caught by trawling or dredging).

Table 4. Threshold estimates of using different threshold variables.

Sample Split	SDG14 Overfishing	SDG14 Trawling
	Model 1	Model 2
The Lagrange multiplier test for no threshold	139.600	118.718
Bootstrap *p*-value	0.0004	0.0001
Threshold estimate	4.4456	4.5516
95% Confidence Interval	(4.396, 4.455)	(4.5077, 4.5523)

In Table 5, 1240 observations are grouped into two regimes. The first regime (SDG14 overfishing) gave 905 observations, and the second included the following 335 observations. The Lagrange multiplier test for no threshold was rejected. The overfishing threshold variable shows nonlinear statistically significant correlations with overall fishing outputs. Furthermore, to gauge the threshold effect, we presume that the single threshold corresponds to the linear and single-threshold models (hypotheses H_0 and H_a). In contrast, the double threshold equals single and double-threshold models (including hypothesis H_0 and H_a), respectively. The results for regime 1 (SDG14 overfishing $\leq$ 4.4456) show that with a higher number of fishing vessels and fishers (coefficient value of 0.412 and 0.623), global fishery outputs may significantly increase. Similarly, the income level and time period are also significantly positively related with fishing production. Specifically, the coefficients for income levels are as follows: high income = 4.017, lower-middle income = 0.951, upper-middle income = 2.221. The results for Regime 2 (SDG14 overfishing > 4.4456), on the other hand, indicate that with a higher number of fishing vessels, the number of fishers may significantly increase global fishery outputs. This finding maintains the sense, but the coefficient values of NFV (0.776) and NF (0.927) are significantly higher than in regime 1. Furthermore, the effects of high income level and time are nonexistent when SDG14 overfishing > 4.4456.

Table 5. Regression results using different threshold variables. Dependent variable: global fishery outputs.

Variables	Panel GLS without threshold	Threshold Model 1 = SDG14 Overfishing		Threshold Model 2 = SDG14 Trawling	
		Regime 1	Regime 2	Regime 1	Regime 2
		Overfishing $\leq$ 4.4456	Overfishing > 4.4456	Trawling $\leq$ 4.5516	Trawling > 4.5516
Constant	−4.402 **	−2.548 **	−10.46 **	−5.106 **	−2.981 **
	[−9.150]	[−5.332]	[−10.524]	[−14.489]	[−4.869]
Logarithm (NFV)	0.552 **	0.412 **	0.776 **	0.728 **	0.283 **
	[10.023]	[7.501]	[7.399]	[18.473]	[7.170]
Logarithm (NF)	0.605 **	0.623 **	0.927 **	0.576 **	0.599 **
	[9.967]	[10.237]	[7.786]	[16.919]	[9.160]
High income (HIC)	4.557 **	4.017 **	−0.358	4.400 **	4.515 **
	[17.689]	[14.543]	[−0.596]	[13.925]	[12.504]
Lower-middle income (LMIC)	1.755 **	0.951 **	1.634 **	1.932 **	1.985 **
	[7.867]	[3.814]	[4.385]	[5.944]	[12.962]
Upper-middle income (UMIC)	3.031 **	2.221 **	3.400 **	2.515 **	3.513 **
	[13.079]	[8.872]	[7.913]	[8.040]	[22.514]
Technological progress (Time trend)	0.0574 **	0.0659 **	0.0255	0.0435 **	0.0809 **
	[5.482]	[6.554]	[1.184]	[10.515]	[8.786]
Observationss	1240	905	335	829	411
Wald χ^2	7848 **	4489 **	3731 **	6797 **	1186 **
Prob > χ^2	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: the t-statistics results are shown in square parentheses (white-corrected for heteroscedasticity). The findings correspond to a 15%-trimmed mean. ** indicate 1% level of statistical significance, respectively.

Regarding the result of the SDG14 trawling threshold estimation, there were 829 observations in regime 1 and 411 observations in regime 2. Similarly, the Lagrange multiplier (LM) test for no threshold thus rejected the null hypothesis. In other words, the global fishery outputs and the trawling threshold variable exhibit statistically significant nonlinear correlations. The results remains the same when using SDG14 overfishing. More precisely, a higher fishery fleet threshold (SDG14 trawling $\leq$ 4.5516) significantly increases the global fishery product (coefficient value of the number of fishing vessels = 0.728) compared with lower thresholds (SDG14 trawling > 4.5516; the coefficient value of the number of fishing vessels = 0.283). In contrast, the number of fishers with the threshold shown in regime 1 (SDG14 trawling $\leq$ 4.5516) increases the fishery outputs significantly less notably (coefficient value of the NF = 0.576) compared to using regime 2 (SDG14 trawling > 4.5516; the coefficient value of the number of NF = 0.599). According to the income level, and replicating the result of threshold SDG14 overfishing, in regime 1 (SDG14 trawling $\leq$ 4.5516), the income level and time positively affect global fishery outputs significantly less notably (high income = 4.400; lower-middle income = 1.932; upper-middle income = 2.515) than regime 2 (SDG14 trawling > 4.5516) (high income = 4.515; lower-middle income = 1.985; upper-middle income = 3.513). This is consistent with our expectation that countries with a high income level will drive greater demand for marine food, leading to increased global fishery outputs.

3.4. Additional Analysis by Controling for the Country GDP Growth and Property Rate

We add the GDP growth rate and poverty ratio for controlling variables and specify our second model (Equation (2)) as follows to generate new estimated threshold values.

$$\begin{aligned} LogGFO_{i,t} = &\left[\alpha_1(Technological\ progress)_{i,t} + \gamma_1 LogNFV_{i,t} + \theta_1 LogNF_{i,t} + \xi_1 LogGDP_{i,t} + \psi_1 LogPoverty\ ratio_{i,t}\right] \times f\left(k_{i,t} \leq \lambda_1^*\right) \\ &+ \left[\alpha_2(Technological\ progress)_{i,t} + \gamma_2 LogNFV_{i,t} + \theta_2 LogNF_{i,t} + \xi_2 LogGDP_{i,t} + \psi_2 LogPoverty\ ratio_{i,t}\right] \times f\left(k_{i,t} > \lambda_1^*\right) \end{aligned} \quad (2)$$

Table 6 demonstrates the results of Equation (2) utilizing two distinct threshold variables of SDG14 overfishing and SDG14 trawling. The threshold value's statistical significance was evaluated based on the *p*-value, estimated using the bootstrap technique with 5000 replications and a 15% trimming percentage. For an additional test, we divided our sample into two separate regimes. The point estimate of the threshold value of SDG14 overfishing is 4.4456, with a 95 percent confidence level ranging from 4.396 to 4.455 for Model 1. Besides, the threshold value for SDG14 trawling in model 2 has an estimate of 4.4038, with a corresponding 95% confidence interval from 4.1596 to 4.4073. Taken together, the number of fishers and fishing vessels in Table 7 keep the same results compared to baseline models (Equation (1)).

Table 6. Threshold estimates of using different threshold variables after adding country control variables (GDP growth rate and poverty rate).

Sample Split	SDG14 Overfishing	SDG14 Trawling
	Model 1	**Model 2**
The Lagrange multiplier test for no threshold	139.600	96.704
Bootstrap *p*-value	0.0004	0.0001
Threshold estimate	4.4456	4.4038
95% Confidence Interval	(4.396, 4.455)	(4.1596, 4.4073)

Table 7. Regression results using different threshold variables after adding country control variables (GDP growth rate and poverty rate). Dependent variable: global fishery outputs.

Variables	Panel GLS without Threshold	Threshold Model 1 = SDG14 Overfishing		Threshold Model 2 = SDG14 Trawling	
		Regime 1	Regime 2	Regime 1	Regime 2
		Overfishing $\leq$ 4.4456	Overfishing > 4.4456	Trawling $\leq$ 4.4038	Trawling > 4.4038
Constant	2.326 **	3.901 **	−5.234 **	−0.0769 **	4.826 **
	[3.234]	[16.980]	[−7.584]	[−0.295]	[18.108]
Logarithm (NFV)	0.493 **	0.423 **	0.488 **	0.966 **	0.243 **
	[10.422]	[20.701]	[7.710]	[28.849]	[9.677]
Logarithm (NF)	0.602 **	0.457 **	1.203 **	0.215 **	0.699 **
	[13.014]	[25.262]	[17.205]	[7.593]	[21.714]
Logarithm of GDP growth rate	0.00163	0.164 **	−0.274 *	0.392 **	−0.331 **
	[0.009]	[3.327]	[−1.911]	[7.926]	[−4.678]
Logarithm of poverty rate	−1.433 **	−1.322 **	−1.096 **	−0.861 **	−1.438 **
	[−25.124]	[−58.985]	[−18.631]	[−19.457]	[−38.016]
Technological progress (Time trend)	0.0117	0.0202 **	−0.00578	0.0379 **	−0.00385
	[1.195]	[5.644]	[−0.515]	[8.648]	[−0.789]
Observations	1240	905	335	558	682
Wald χ^2	6932 **	6216 **	3137 **	5044 **	5705 **
Prob > χ^2	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: The *t*-statistics results are shown in square parentheses (white-corrected for heteroscedasticity). The findings correspond to a 15% trimming percentage. * and ** indicate 5% and 1% level of statistical significance, respectively.

As shown in Table 7, interestingly, the results for regime 1 (SDG14 overfishing $\leq$ 4.4456) show that with a higher GDP growth rate (coefficient value of 0.164), global fishery outputs would be significantly increased, compared to SDG14 overfishing > 4.4456 (Regime 2), as GDP growth rate in these countries increases, their fishery production will reduce (coefficient value of the GDP growth rate = −0.274). We also duplicated the result of threshold SDG14 trawling in regime 1 (SDG14 trawling $\leq$ 4.4038) and found that the GDP growth rate positively affects global fishery outputs (coefficient value of 0.392) in comparison to countries with a high proportion of trawl net use (SDG14 trawling > 4.4038), meaning that fishery resources decrease significantly when using more trawling nets in countries.

In terms of the poverty rate for both threshold values of SDG14 overfishing and SDG14 trawling, we discovered that poverty rates are significantly negative to fishery outputs. This implied that as the poverty ratio in these countries increased, their fishery production decreased significantly compared with countries with a low proportion of overfishing and trawling. Overfishing and trawling net use are much more complex concerns in countries with high poverty ratios, and poverty drives poor fishers to deplete stocks far below levels at which bioeconomic balance would generally be reached.

4. Discussions

Regarding countries with a high proportion of overfishing activities (SDG14 overfishing > 4.4456), as the number of fishing vessels and the number of fishermen operating in these countries increased, their fishery production also increased significantly compared with countries with a low proportion of overfishing, but at the same time, this also led to an increase in overfishing or the presence of fish species lacking their required resources. Prior studies have proposed taxing overfished species or limiting the operation of fishing vessels as policy management tools [38,75–77]. Furthermore, implementing a wide range of policies such as subsidies and vessel buybacks has been suggested by Milazzo (1998) [78] as a “green subsidy”. The aim of the vessel buyback agendas is to lessen fleet overfishing, which improves the sustainability of the fishing industry and resource conservation [78]. Switching capacity-enhancing subsidies from fishing for reduced fish stocks to sustainable activities, such as promoting “fishing for plastic” instead of depleted fish stocks, is a high priority that would still allow fishers to receive subsidies [68].

On the other hand, in countries with a relatively high proportion of trawl net use (SDG14 trawling > 4.5516), as the number of fishing vessels increases in these countries, their fishery outputs are significantly reduced in comparison to countries with a low proportion of trawl net use, meaning that the use of trawl nets has a negative impact on fishery resources. For example, Hong Kong's trawl ban policy, which aims to restore marine biodiversity and fisheries resources, offers an excellent opportunity to mitigate the adverse effects of trawling [79]. After two and a half years of trawling in Hong Kong waters, significant biodiversity improvements were shown [20,79]. Additionally, there have been attempts at implementing similar trawl bans in Canada and Italy, with mixed results [80,81].

We also found that in countries with a high overfishing ratio (SDG14 overfishing > 4.4456), such as low-income countries, fishery outputs are significantly higher than in middle-income and high-income countries, and specifically, low-income countries display a lower production of fishing vessels, often investing more manpower in increasing fishery production. The physical risk in fishery production will increase significantly and cause biodiversity to decrease and marine ecosystems to suffer damage. People suffer from fishery income and employment problems when the ocean ecosystem is damaged [82,83]. Furthermore, regarding countries with a high proportion of overfishing and trawling activities (threshold values: SDG14 overfishing > 4.4456; SDG trawling > 4.4038), as the GDP annual growth rate in these countries increased, their fishery production also decreased significantly compared with countries with a low proportion of overfishing and trawling, but at the same time, this also led to a decrease in overfishing and trawling net use. Interestingly, we also found that overfishing and trawling net use are much more complex problems in countries with high poverty ratios, and that poverty drives poor fishers to deplete stocks far below levels at which bioeconomic equilibrium would usually be achieved, which is consistent with prior studies [84,85]. Hence, providing appropriate fisheries management and alleviating poverty policies in these areas should be a priority, aiming to protect the vulnerable ecosystems in these regions [84,86].

Advances in science and technology enable humans to collect more data more quickly [87,88], and also to detect changes in the status of fish groups in a timely manner, so that they can be intervened in effectively. By using catch control principles, overfishing can be avoided when fish stocks decline, regardless of the cause of the decline. In the face of the problem of ocean productivity, it may be feasible to use a strategy such as this. Several areas of the United States already employ these types of fishing control principles [89]. In fact, fisheries have successfully used this method for capturing unstable stocks such as sardines and anchovies [90], as have fisheries focused on long-lived demersal fish [89].

International agreements, such as the Parties to the Nauru Agreement (PNA) ship-related scheme, have been used to regulate and control a variety of fish stocks (tuna) and thus reduce disputes and accommodate changes in fish populations and distributions. When the abundance or distribution of tuna changes, the quantity of tuna catch allocated to each PNA member country will change [91]; the catch allowance can also be shared between countries to avoid overfishing when the fish stocks change. In addition, there are precedents for compensatory payments (e.g., the US/Canada Pacific Salmon Treaty) and the trading of fishing rights (e.g., between Norway and Russia), which act as countermeasures between economic zones [92]. Introducing management systems or measures that encourage fishermen to reduce their catches of specific fish stocks can reduce the risk of fish stock depletion, ecosystem damage and fishery closures. For example, the change in the catch sharing system for bottom fish can reduce the fishing of endangered species [93].

5. Conclusions

Using panel data from 62 countries, this study applied a threshold panel data model to empirically explore the possible threshold effects of SDG14. It used distinct overfishing (SDG14 overfishing) and fish caught by trawling or dredging techniques (SDG14 trawling) as the threshold variables to examine the nonlinear interaction between the factors affecting the fishery fleet, fishers, and fishery outputs. Regarding overfishing and bottom trawling impacts, the study supports a single-threshold effect. The results demonstrate that various combinations of the primary components may enhance the levels of global fishery output (the number of fishers, fishing vessels, and income levels). The threshold value effect has various implications for fishermen regarding their fishing output.

The regime 1 results (low SDG14 overfishing) indicate that the numbers of fishery fleets and fishers, and income levels, positively increase fishery outputs, which effect remains the same when using the alternative threshold of SDG14 trawling. In regime 2 (high overfishing), the high income level and time factors are insignificant and inconsistent with baseline regression. In contrast, the other variables retain a similar level of significance, but their coefficient values are significantly greater than those of low fishing stocks. As for the threshold variable low bottom trawling, we find that the number of fishers, income levels, and time positively affect global fishery outputs slightly less significantly than in countries with high bottom trawling. In contrast, the result regarding fishing vessels is also significantly positive, but this coefficient is lower in cases with high trawling. This finding implies that countries with greater investments in trawl nets will endanger fishery resources due to the bycatching and discarding of non-target species; this is consistent with prior reports that bottom trawling accounted for approximately 23% of landed marine catches and 60% of fisheries' discards globally, from 1950 to 2014 [50,51].

Finally, we discovered that in countries with high rates of overfishing, such as low-income nations, their fishery outputs are significantly higher than those of middle- and high-income countries. In particular, substantial investments in staffing or subsidies in low-income nations may lead to overfishing and impact global fishery production in the long term [94,95].

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Appendix A. Definition of Variables

Indicators	Definition	Measurement unit	Sources
Dependent variable			
GFO	Global fishing outputs is the cultivation of aquatic organisms such as fish, mollusks, aquatic plants, and crabs. Farming requires specific rearing process interventions to improve production, such as frequent stocking, feeding, predator protection, etc., which pertain specifically to aquaculture products meant for final harvest for consumption.	Tons live weight	Food and Agriculture Organization of the United Nations (FAO) https://www.fao.org/fishery/en/statistics, accessed on 17 August 2022
Threshold variables			
SDG14 Overfishing	Fish grabbed from overfishing or tumbled stocks	% of total catch	Sustainable development reporting https://dashboards.sdgindex.org/rankings, accessed on 17 August 2022
SDG14 Trawling	Fish grabbed by trawling or dredging	% of fish caught by trawling	
Countries control variables			
NFV	The global number of fishing vessels is the number of boats or ships used to catch fish in the sea, on a lake, etc.	Number of motorized vessels propelled by engines	Food and Agriculture Organization of the United Nations (FAO) https://www.fao.org/fishery/en/statistics, accessed on 17 August 2022
NF	Global number of fishers is the total number of people who work full-time in the commercial fishing industry in freshwater, brackish water, and marine habitats to capture and land all aquatic creatures and plants.	Number of fishers	
HIC	High income	Dummy variable	
LMIC	Lower-middle income	Dummy variable	
UMIC	Upper-middle income	Dummy variable	
Technological progress (Time trend)	Time takes values from 1 to 20 for years between 2001 and 2020: 2001 = 1, 2002 = 2, . . . 2020 = 20.	Number	
GDP growth rate	Gross domestic product annual growth rate	Annual percentage	World Development Indicators, The World Bank https://databank.worldbank.org/source/world-development-indicators, accessed on 17 August 2022
Poverty rate	Proportion of poverty headcount at national poverty lines	Percentage of population	

Appendix B. The Groups of Species of Global Fishery Outputs by Continent (Measurement Unit: Tons Live Weight)

Continent	ASFIS Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Africa	Aquatic Animals NEI	-	-	-	-	-	1	1	1	1	1
Africa	Aquatic Plants	83,592	117,188	105,561	79,492	81,158	88,530	96,267	119,311	114,132	138,329
Africa	Crustaceans	32	32	15	10	12	7	8	12	12	4
Africa	Crustaceans	5824	8411	8570	7884	11,919	10,587	9644	9242	3968	5701
Africa	Demersal Marine Fish	100,753	118,054	142,292	139,912	168,590	234,809	256,915	223,014	227,051	164,650
Africa	Freshwater and Diadromous Fish	297,489	324,675	366,077	408,994	463,477	506,358	550,954	706,978	754,869	1,112,276
Africa	Marine Fish NEI	43	17	16	15	23	17	1	11	35	18
Africa	Molluscs excl. Cephalopods	1533	1696	1921	2049	2074	2332	2662	2812	2775	3034
Africa	Pelagic Marine Fish	1	9	152	91	366	604	517	613	380	373
Americas	Aquatic Animals NEI	693	735	728	728	797	820	746	949	968	871
Americas	Aquatic Plants	65,608	71,829	40,104	20,283	15,512	38,234	26,402	28,038	88,733	12,932
Americas	Crustaceans	206,581	272,388	340,109	367,022	422,576	499,748	503,061	530,940	525,049	560,834
Americas	Demersal Marine Fish	2244	2287	656	1805	2223	2214	2609	2197	2323	1967
Americas	Freshwater and Diadromous Fish	1,250,587	1,286,977	1,311,579	1,375,873	1,422,785	1,476,098	1,441,335	1,500,145	1,516,139	1,420,627
Americas	Marine Fish NEI	25	24	5	9	-	-	1	5	8	2
Americas	Molluscs excl. Cephalopods	239,211	238,282	282,194	393,052	323,835	384,666	408,607	431,474	417,776	527,056
Americas	Pelagic Marine Fish	532	541	570	4261	4640	5004	3752	4095	3898	3269
Asia	Aquatic Animals NEI	182,666	186,754	331,465	375,808	425,463	464,650	505,831	614,948	720,963	790,435
Asia	Aquatic Plants	10,781,141	11,691,332	12,464,506	13,773,982	14,726,157	15,513,891	16,212,167	17,109,776	18,444,553	20,008,197
Asia	Crustaceans	1,759,554	1,929,317	2,648,350	3,007,946	3,337,173	3,833,752	4,279,664	4,470,283	4,756,460	4,905,196
Asia	Demersal Marine Fish	182,352	211,239	529,909	572,340	634,916	666,357	704,565	726,825	742,121	734,873
Asia	Freshwater and Diadromous Fish	18,314,993	19,453,023	19,987,314	21,873,479	23,318,699	24,817,123	26,360,428	28,573,708	29,870,489	31,586,011
Asia	Marine Fish NEI	477,758	541,287	219,605	238,503	279,932	330,340	323,394	540,757	436,285	460,565
Asia	Molluscs excl. Cephalopods	9,219,565	9,866,930	10,261,153	10,640,295	10,994,804	11,441,253	11,804,560	11,831,314	12,200,074	12,477,154
Asia	Pelagic Marine Fish	163,604	172,228	193,159	187,420	198,576	227,291	244,940	243,986	279,708	278,688
Asia	Others	35	32	2924	13,046	16,407	21,267	21,203	24,275	19,223	61,115
Europe	Aquatic Animals NEI	5	-	-	4	-	25	25	55	148	478
Europe	Aquatic Plants	542	181	104	253	290	851	363	1326	1870	2058
Europe	Cephalopods	16	14	8	12	16	11	27	30	15	10
Europe	Crustaceans	2725	2538	3236	3244	3278	3331	3252	3266	3379	3285
Europe	Demersal Marine Fish	116,212	108,978	132,664	121,215	141,221	155,366	172,614	182,780	191,260	193,266
Europe	Freshwater and Diadromous Fish	1,226,100	1,263,484	1,313,460	1,347,136	1,307,027	1,330,771	1,488,822	1,518,792	1,658,491	1,716,060
Europe	Marine Fish NEI	1991	1593	3891	2973	4012	4879	5897	5460	5892	5443
Europe	Molluscs excl. Cephalopods	746,304	666,992	709,370	697,961	679,485	696,196	694,292	615,097	657,376	604,396
Europe	Pelagic Marine Fish	1260	1917	1803	10,698	8616	16,751	17,776	12,543	10,221	10,231
Oceania	Aquatic Animals NEI	480	342	1134	941	2065	2273	2137	1892	1550	1852
Oceania	Aquatic Plants	12,514	5104	4604	6095	8139	11,381	2628	3202	6557	12,809
Oceania	Crustaceans	5217	5993	5712	6304	6089	6190	5544	5498	6160	6770
Oceania	Demersal Marine Fish	7	7	1	2	1	2	-	-	-	-
Oceania	Freshwater and Diadromous Fish	25,211	25,780	23,042	24,496	27,622	32,859	39,360	40,310	48,096	51,486

Continent	ASFIS Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Oceania	Marine Fish NEI	190	159	1532	1410	2508	2462	3253	3966	4947	5649
Oceania	Molluscs excl. Cephalopods	81,096	92,149	93,267	102,669	113,025	115,647	120,658	120,741	110,933	116,610
Oceania	Pelagic Marine Fish	3889	4008	2373	4554	2231	3611	2139	4532	8786	7284
Oceania	Others	877	1285	1954	1849	2900	2420	2210	1903	1866	2145
Africa	Aquatic Animals NEI	1	1	1	1	25	37	101	63	63	60
Africa	Aquatic Plants	141,120	161,458	123,194	149,368	196,570	139,359	136,833	113,875	110,373	104,090
Africa	Crustaceans	6977	6382	11527	12339	3732	4643	6171	5581	4888	7618
Africa	Demersal Marine Fish	166,047	175,332	159,849	170,154	211,781	239,006	325,176	347,135	362,527	453,845
Africa	Freshwater and Diadromous Fish	1,220,024	1,305,182	1,444,882	1,530,740	1,557,634	1,728,811	1,691,354	1,879,181	1,903,076	1,781,492
Africa	Marine Fish NEI	19	15	17	1	-	-	-	-	-	-
Africa	Molluscs excl. Cephalopods	2741	3269	3903	4475	4919	5959	5527	5836	7351	5994
Africa	Pelagic Marine Fish	350	841	380	549	199	218	-	-	-	1194
Americas	Aquatic Animals NEI	900	891	743	857	821	664	706	591	478	370
Americas	Aquatic Plants	15,443	5029	13,332	13,641	12,818	15,727	17,694	22,244	28,067	25,315
Americas	Crustaceans	618,364	637,099	614,514	703,004	792,808	792,922	861,838	1,000,688	1,164,234	1,266,090
Americas	Demersal Marine Fish	1859	2076	2425	2130	2070	1931	2026	4286	4468	5300
Americas	Freshwater and Diadromous Fish	844,409	914,932	937,817	1,082,143	1,017,448	1,042,779	1,092,918	1,130,032	1,149,848	1,179,727
Americas	Freshwater and Diadromous Fish	751,734	910,725	875,063	1,010,734	990,251	892,436	1,008,046	1,040,804	1,137,781	1,225,123
Americas	Marine Fish NEI	-	-	601	714	619	611	628	1276	1518	1340
Americas	Molluscs excl. Cephalopods	552,648	521,578	546,649	538,136	464,780	573,990	609,277	659,382	727,752	688,077
Americas	Pelagic Marine Fish	4929	3247	8579	11,056	10,386	11,681	8571	11,936	9022	9206
Asia	Aquatic Animals NEI	713,393	777,976	829,036	828,958	843,550	906,681	923,813	914,231	972,685	1,052,345
Asia	Aquatic Plants	21,597,225	24,480,914	27,837,570	28,878,515	30,841,267	31,473,785	32,442,126	33,281,704	34,427,039	34,916,316
Asia	Crustaceans	5,176,715	5,369,903	5,595,283	6,030,841	6,312,175	6,871,655	7,759,255	8,454,936	9,370,474	9,951,148
Asia	Demersal Marine Fish	783,216	846,950	896,385	970,249	1,051,938	1,094,310	1,240,763	1,301,177	1,422,748	1,519,924
Asia	Freshwater and Diadromous Fish	32,715,476	34,944,744	37,387,252	39,060,979	40,836,410	42,593,525	43,736,146	45,211,394	46,419,231	47,260,766
Asia	Marine Fish NEI	552,319	560,543	596,918	653,765	639,088	676,692	718,286	724,768	761,000	858,180
Asia	Molluscs excl. Cephalopods	266,545	264,060	259,436	521,244	259,516	257,793	226,562	209,427	201,725	192,671
Asia	Molluscs excl. Cephalopods	12,257,179	12,873,857	13,453,885	13,928,542	14,404,018	15,278,828	15,706,153	15,859,689	15,721,931	16,158,709
Asia	Pelagic Marine Fish	313,580	350,480	355,587	326,088	333,196	342,557	379,443	386,760	402,389	390,617
Asia	Others	50,658	19,601	30,923	46,218	39,158	53,018	64,143	25,589	631	473
Europe	Aquatic Animals NEI	250	323	349	928	917	2200	2196	2827	5052	6671
Europe	Aquatic Plants	2071	2869	2678	2819	2531	1640	2032	5373	11388	21792
Europe	Cephalopods	3	5	2	1	1	1	2	1	1	-
Europe	Crustaceans	3462	3293	3213	3275	3373	3373	3368	3444	3585	3563
Europe	Demersal Marine Fish	181,102	178,726	174,583	169,504	168,358	183,819	194,580	197,370	205,799	198,140
Europe	Freshwater and Diadromous Fish	1,840,173	2,065,497	2,009,110	2,127,983	2,157,742	2,149,894	2,177,825	2,173,721	2,391,459	2,440,403
Europe	Marine Fish NEI	2422	2219	1519	1229	1474	1263	1396	3124	1633	5823
Europe	Molluscs excl. Cephalopods	618,528	579,284	563,639	620,721	620,430	628,579	646,253	687,470	621,891	578,712
Europe	Pelagic Marine Fish	8536	8840	11,710	10,849	15,376	18,840	20,479	28,289	23,265	29,303

Continent	ASFIS Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Oceania	Aquatic Animals NEI	3536	2841	3645	1354	5593	4772	3993	973	2899	2844
Oceania	Aquatic Plants	12,508	17,400	16,864	23,229	20,336	15,153	9,750	10,200	10,190	10,065
Oceania	Crustaceans	5824	5956	5613	5700	6862	6543	6434	6108	6619	8597
Oceania	Demersal Marine Fish	7	10	9	13	24	29	37	35	29	31
Oceania	Freshwater and Diadromous Fish	58,030	63,777	61,396	58,749	67,695	75,911	74,909	86,605	77,750	89,267
Oceania	Marine Fish NEI	3625	1538	890	579	1098	2018	2294	2487	2951	3068
Oceania	Molluscs excl. Cephalopods	120,789	104,624	101,947	114,684	94,316	111,818	118,272	101,904	113,966	116,363
Oceania	Pelagic Marine Fish	5800	7087	7486	7544	8418	8895	8100	8000	8252	8345
Oceania	Others	2868	2574	2610	1985	1799	1218	1210	1210	1210	1210

Note: Unit of measurement: tons live weight; The group of species categorized by ASFIS species. Source: Food and Agriculture Organization of the United Nations (FAO), from the website: https://www.fao.org/fishery/en/statistics, accessed on 17 August 2022.

Appendix C. The Groups of Species of Global Fishery Outputs by World Bank Income Classification

Country	ASFIS Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
HIC	Aquatic Animals NEI	48,811	36,548	27,504	30,081	30,625	26,925	25,660	24,092	32,551	30,805
HIC	Aquatic Plants	966,192	1,143,999	982,130	1,060,976	1,146,877	1,299,863	1,342,762	1,413,017	1,408,800	1,352,987
HIC	Cephalopods	16	14	8	12	16	11	27	30	15	10
HIC	Crustaceans	52,647	68,312	87,599	85,636	91,186	90,787	102,791	108,862	100,242	105,987
HIC	Demersal Marine Fish	251,175	269,771	331,714	309,347	338,080	351,024	379,259	395,435	409,371	376,880
HIC	Freshwater and Diadromous Fish	2,369,963	2,399,951	2,466,081	2,525,324	2,494,064	2,556,448	2,651,428	2,670,068	2,755,598	2,681,088
HIC	Marine Fish NEI	14,426	14,149	16,816	14,915	16,366	17,363	20,717	20,268	23,766	26,330
HIC	Molluscs excl. Cephalopods	1,791,519	1,756,050	1,913,145	1,990,836	1,897,647	2,074,066	2,200,864	2,000,511	2,033,211	2,053,695
HIC	Pelagic Marine Fish	168,737	178,161	172,808	176,810	182,098	186,136	191,863	180,244	182,320	163,949
HIC	Others	902	1311	1985	1865	2916	2447	2237	1926	1889	2167
LIC	Aquatic Animals NEI	-	-	-	10	50	51	101	101	101	126
LIC	Aquatic Plants	444,995	446,565	450,325	446,015	445,765	449,800	448,690	448,720	448,200	449,400
LIC	Crustaceans	5411	7928	7359	6679	8214	9810	9456	8757	3789	4822
LIC	Freshwater and Diadromous Fish	19,374	23,191	25,504	26,503	31,808	54,645	73,458	75,553	101,041	121,874
LIC	Molluscs excl. Cephalopods	60,000	60,000	60,000	60,000	60,000	60,020	60,020	60,120	60,220	60,220
LMIC	Aquatic Animals NEI	-	25	40	42	96	116	114	490	28,184	31,240
LMIC	Aquatic Plants	1,109,060	1,255,327	1,345,709	1,733,369	2,372,211	2,752,820	3,342,265	3,947,178	4,841,142	5,886,379
LMIC	Crustaceans	586,820	648,564	760,193	893,952	1,036,632	1,118,234	1,096,986	1,165,178	1,145,230	1,126,726
LMIC	Demersal Marine Fish	115,193	138,286	162,099	158,087	187,350	249,381	269,106	239,061	245,392	185,150
LMIC	Freshwater and Diadromous Fish	4,675,907	5,030,920	5,552,321	6,478,141	7,083,636	7,713,803	8,447,715	9,925,845	10,281,891	11,744,244
LMIC	Marine Fish NEI	28,990	35,083	40,292	49,281	55,576	118,670	86,617	254,231	181,647	214,524

Country	ASFIS Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LMIC	Molluscs excl. Cephalopods	85,243	101,822	131,814	191,384	187,263	196,324	223,507	234,065	235,880	171,143
LMIC	Pelagic Marine Fish	16	17	170	98	262	528	950	2649	2298	956
LMIC	Others	-	1	2867	12,992	16,349	16,349	16,001	19,663	15,857	58,079
UPMIC	Aquatic Animals NEI	135,033	151,258	305,783	347,348	397,554	440,677	482,865	593,162	662,794	731,465
UPMIC	Aquatic Plants	8,423,150	9,039,743	9,836,715	10,639,745	10,866,403	11,150,404	11,204,110	11,452,738	11,957,703	12,485,559
UPMIC	Crustaceans	1,334,997	1,493,820	2,150,790	2,406,102	2,644,992	3,134,759	3,591,913	3,736,422	4,045,746	4,244,243
UPMIC	Demersal Marine Fish	35,160	32,451	311,401	367,557	421,232	458,067	488,113	500,107	507,807	532,554
UPMIC	Freshwater and Diadromous Fish	14,044,467	14,894,818	14,952,631	15,993,666	16,923,806	17,836,569	18,706,196	19,666,546	20,707,444	21,337,143
UPMIC	Marine Fish NEI	436,590	493,848	167,941	178,714	214,533	201,665	225,212	275,700	241,725	230,807
UPMIC	Molluscs excl. Cephalopods	8,350,940	8,948,175	9,242,944	9,593,783	9,968,309	10,309,682	10,546,385	10,706,741	11,059,622	11,443,192
UPMIC	Pelagic Marine Fish	532	521	25,079	30,114	32,061	66,588	76,295	82,848	118,350	134,924
UPMIC	Others	10	5	26	39	43	4891	5175	4589	3344	3015
HIC	Aquatic Animals NEI	28,640	24,111	26,583	27,926	48,658	65,945	55,691	60,249	50,739	51,548
HIC	Aquatic Plants	1,362,855	1,471,995	1,567,462	1,475,191	1,610,419	1,758,272	2,187,546	2,123,924	2,183,809	2,180,819
HIC	Cephalopods	3	5	2	1	1	1	2	1	1	-
HIC	Crustaceans	95,620	86,244	87,359	112,789	118,834	131,493	138,867	162,821	172,917	160,956
HIC	Demersal Marine Fish	353,688	360,612	364,777	378,679	381,007	385,915	408,172	405,625	417,456	415,385
HIC	Freshwater and Diadromous Fish	2,923,440	3,337,750	3,226,558	3,468,081	3,428,471	3,293,062	3,445,749	3,470,853	3,753,319	3,880,933
HIC	Marine Fish NEI	22,421	9782	11,260	13,486	9249	10,252	11,436	13,014	11,976	16,566
HIC	Molluscs excl. Cephalopods	2,002,476	1,972,154	1,839,422	2,001,602	1,966,128	2,055,385	2,133,868	2,226,744	2,187,898	2,088,811
HIC	Pelagic Marine Fish	167,390	193,669	188,172	175,143	186,149	190,080	192,760	201,496	197,455	202,262
HIC	Others	2877	2593	2631	2004	1818	1238	1230	1231	1229	1226
LIC	Aquatic Animals NEI	136	141	146	146	175	186	264	215	215	215
LIC	Aquatic Plants	447,129	446,842	450,035	509,110	517,497	570,613	570,617	608,547	612,075	611,164
LIC	Crustaceans	6066	5096	5377	4696	3452	4139	5439	4947	4308	5273
LIC	Demersal Marine Fish	6	75	145	165	15	15	15	15	15	15
LIC	Freshwater and Diadromous Fish	113,084	131,021	133,449	148,061	157,777	164,447	173,820	167,677	168,143	195,506
LIC	Marine Fish NEI	-	-	-	65	65	65	80	120	120	120
LIC	Molluscs excl. Cephalopods	60,220	60,220	60,270	60,270	60,270	60,270	62,320	62,420	62,420	62,420
LMIC	Aquatic Animals NEI	5074	5609	7218	20735	7093	6850	8410	7269	14,090	13,224
LMIC	Aquatic Plants	7,182,520	8,468,204	11,012,765	11,809,920	13,060,792	12,604,842	12,109,910	11,943,968	11,407,845	11,210,375
LMIC	Crustaceans	1,377,612	1,386,460	1,751,470	2,016,426	2,142,801	2,338,030	2,775,903	2,844,304	3,187,139	3,436,716
LMIC	Demersal Marine Fish	183,898	195,679	188,546	191,449	236,946	258,227	396,200	378,561	389,048	477,291
LMIC	Freshwater and Diadromous Fish	12,326,745	13,860,385	15,189,862	15,926,170	16,705,250	17,899,023	18,964,905	20,590,216	21,756,243	22,060,390
LMIC	Marine Fish NEI	262,837	250,932	243,287	253,792	193,009	232,871	255,316	259,814	279,827	288,311
LMIC	Molluscs excl. Cephalopods	185,297	206,242	253,919	258,627	294,898	333,637	349,787	429,493	352,229	357,712
LMIC	Pelagic Marine Fish	1007	12,610	2571	3242	1999	1857	1704	1507	3639	5647
LMIC	Others	48,449	17,251	29,091	44,399	37,505	51,406	63,181	24,863	-	-

Country	ASFIS Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
UPMIC	Aquatic Animals NEI	684,230	752,170	799,827	783,292	794,979	841,374	866,445	850,952	916,132	997,303
UPMIC	Aquatic Plants	12,775,863	14,280,629	14,963,377	15,273,351	15,884,812	16,711,935	17,740,362	18,756,957	20,383,328	21,075,219
UPMIC	Crustaceans	4,332,032	4,544,821	4,385,933	4,621,235	4,853,851	5,205,465	5,716,847	6,458,675	7,185,428	7,634,064
UPMIC	Demersal Marine Fish	594,538	646,550	679,622	741,559	816,077	874,821	958,119	1,065,722	1,188,976	1,284,455
UPMIC	Freshwater and Diadromous Fish	22,064,478	22,875,602	24,165,553	25,328,941	26,335,607	27,126,752	27,196,708	27,292,974	27,401,423	27,839,930
UPMIC	Marine Fish NEI	273,117	303,601	345,398	388,945	439,956	437,397	455,771	458,706	475,179	563,415
UPMIC	Molluscs excl. Cephalopods	11,570,434	12,108,048	12,775,836	13,407,238	13,526,672	14,407,664	14,765,973	14,804,994	14,792,062	15,231,576
UPMIC	Pelagic Marine Fish	164,792	164,216	192,999	177,701	179,428	190,254	222,128	231,982	241,834	230,755
UPMIC	Others	2199	2331	1812	1800	1634	1592	941	705	612	456

Note: Unit of measurement: tons live weight; The group of species categorized by ASFIS species; HIC = High income; LMIC = Lower-middle income; UMIC = Upper-middle income; LIC = Low income. Source: Food and Agriculture Organization of the United Nations (FAO), from the website: https://www.fao.org/fishery/en/statistics, accessed on 17 August 2022.

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