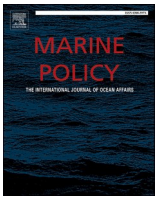
Marine Policy 171 (2025) 106474

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol



Unveiling the hidden hands: Analysis of corporate ownership of industrial tuna fishing vessels in the Eastern Pacific Ocean

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ARTICLE INFO

Keywords:
Global fisheries governance
Ownership analysis
Tuna
Equity
Eastern Pacific Ocean, (EPO)

ABSTRACT

Distant-water fishing (DWF) refers to fishing operations conducted by companies in waters beyond their national exclusive economic zones (EEZs), often targeting the EEZs of other coastal states or international waters. Research on DWF typically emphasizes the flag states of vessels, rather than the nationalities of the corporations that own them, despite evidence of efforts to obscure ownership. This paper examines the corporate owners of 1648 industrial and semi-industrial tuna fishing vessels in the Eastern Pacific Ocean (EPO) using Orbis data, analyzing ownership at three levels: flag state, direct corporate owners, and ultimate corporate owners. Results show that flag state data alone understate the true fishing capacity of key DWF nations. Shifts in ownership nationality across levels are significant, notably for Taiwanese and Spanish corporations owning vessels through proxies in the Global South. These ownership shifts impact 6 % of vessels and 14 % of gross tonnage in the registered EPO tuna fleet. Furthermore, spatial analysis using Global Fishing Watch data highlights the Galapagos Islands EEZ as a critical fishing zone, frequently accessed by foreign fishing corporations through Ecuadorian intermediaries. This study underscores the need to incorporate ownership data into fisheries governance for greater transparency and accountability. The systematic collection and analysis of ownership data would allow fisheries managers to better monitor capacity, address power concentration, and promote policies that ensure fairer distribution of resources and benefits.

1. Introduction

The capacity and geographical scope of industrial fishing has increased dramatically since the 1950s [1,2], driven by the overexploitation of domestic coastal waters [2,3], increasing global demand for seafood [4], rapid technological innovation [1,5,6], and rampant supply of government subsidies [7–11]. However, this expansion has been highly unequal, dominated by a few wealthy countries [1,12–14], and corporate actors [15–17]. Analyses of the scope and impact of distant water fishing (DWF) are commonly conducted at state level (i.e., vessel flag) [1,2,14]. However, since vessels are predominantly operated by private companies, not states [17,18], and given the frequent use of flags of convenience [19–21], we argue that the full extent of DWF cannot be understood without the identification of the corporate actors that own, operate, and ultimately benefit from those fleets.

1.1. Industrial DWF fleets are dominated by rich countries in the Global North

Industrial fishing vessels are now ubiquitous across much of the world's ocean, from coastal waters to the high seas. Vessels flagged to higher-income countries are considered responsible for 97 % of industrial fishing effort on the high seas, of which 86 % is attributed to five countries (China, Taiwan, Japan, South Korea, Spain) [14]. The coastal waters of lower-income countries also provide key fishing grounds for industrial fishing vessels, with as much as 78 % of global effort recorded

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https://doi.org/10.1016/j.marpol.2024.106474
Received 16 April 2024; Received in revised form 16 October 2024; Accepted 24 October 2024
Available online 7 November 2024

in these countries' Exclusive Economic Zones (EEZs) [14].Although industrial fisheries rely strongly on access to foreign waters in the Global South (high seas and EEZs), landings of high-value species are predominantly destined for markets in affluent countries in the Global North [22,23]. Producers in the Global South aspiring to enter these same high-value international markets face multiple barriers such as complex logistics and strict quality standards that effectively confine them to local markets [24]. Furthermore, lower-income countries often lack the capacity to effectively exploit their own valuable marine resources and instead enter into fishing access agreements with DWF nations in return for compensation [25–28]. Such access arrangements take various forms including 'first generation access agreements' where one government grants access to another in return for financial payment and 'second-generation' agreements where access and other benefits (e.g., reduced licensing costs, tax breaks, access to land) are offered to foreign vessel owners who register their vessels locally in order to make use of local goods and services, and/or establish onshore processing facilities through joint ventures (see [29]).

While access agreements provide a legal framework for DWF nations and foreign vessel owners to fish within a coastal state's EEZ, questions remain about their sustainability and equitability [28,29]. DWF fleets portray a high risk of illegal, unreported, and unregulated (IUU) fishing, often within the EEZs of low-income countries [30–32], which can lead to conflicts over space and resources with local, often small-scale, fishers, jeopardizing domestic livelihoods and heightening the likelihood of food insecurity among coastal communities [31,33–36]. Furthermore, access agreements have been criticized for being opaque, coercive, and imbalanced [27,28,37], disproportionately benefiting DWF nations (resource seekers) while casting host countries (resource holders) into a position of dependency on the Global North [38–40]. Stäbler *et al.* [34] suggest that DWF nations instrumentalize existing power imbalances to target fishing effort in those countries where governance is lacking, and shape access agreements in their favor. Standing [41] argues that this lack of governance may be the result of DWF fleet presence, whereby state-corporate power facilitates feeble regulatory institutions and management solutions that advance corporate interests; "*corporations do not react to imperfect institutions; they can be integral to their creation*" [41]. This can create a reliance on the foreign investment that access agreements and DWF vessels bring, which can also be a prerequisite for access to aid and development funding [42], and important for for ensuring high trade volume and increasing the likelihood of international trade [39]. Thus, the dominance of the world's industrial fishing fleet by wealthy countries in the Global North and the dependency of coastal states in the Global South on their activities, persists. The entrenched systems and relationships make change unlikely without fundamental reform to existing fisheries governance and international trade.

1.2. Lack of transparency in global fisheries governance

Existing lack of transparency in fisheries governance is recognized as an obstacle to achieving sustainable and equitable fisheries [43]. Calls to improve transparency in fisheries governance focus on several key areas: seafood labeling and international supply chains [44,45], vessel tracking and transparency of at-sea activities [46], and negotiations and decision-making regarding allocation of access, fishing access agreements, and enforcement actions [34,47,48]. Despite some advances (e.g., the adoption of an IUU vessel list by RFMOs), implementation of efforts to increase transparency and enforcement sometimes fall short because of a lack of clarity over the objectives and who is ultimately responsible, and should be held accountable [49]. Recently, there has been a focus on the flow of finances, financial accountability, government subsidies, and tax justice to achieve biodiversity goals [50] and foster responsible ocean governance [51,52]. However, analysis of such flows is often obstructed by the so-called '*corporate veil*' [41,53]. Standing [41] argues that illegal fishing is to an extent embedded in the business strategies and ownership structures of multinational corporate entities (and should not be seen as just distinct from 'legal fishing').

Identifying the ultimate owners of corporate fishing firms is challenging due to sometimes opaque ownership structures consisting of global networks of subsidiary companies [17,53]. Large corporate fishing firms can use a range of tactics to circumvent regulations and maximize profits [54], including flags of convenience and frequent flag changes [55], use of joint ventures [56], shell companies and tax havens [52,57], and maintaining close ties with decision-makers [41]. Thus, unraveling complex ownership networks and identifying ultimate ownership of fishing vessels is essential for holding owners accountable in case of fishing violations, infractions on labor law [19], or tax evasion and money laundering [57,58], and to ultimately increase transparency.

However, few detailed analyses exist of the corporate actors behind global industrial fishing, and most of them are not peer-reviewed [16,17,21,59–64]. While evidence supports that fishing capital is increasingly concentrated in the hands of a few transnational corporations, more empirical research is needed to understand the true ownership structure in specific fisheries, notably those with global value chains. This research should guide improved decision-making in global fisheries governance, notably the development of a global, transparent, and standardized ownership register for fishing vessels.

1.3. Case study: tuna vessels in the Eastern Pacific Ocean

In this paper, we identify the corporate owners of registered tuna fishing vessels operating in the Eastern Pacific Ocean (EPO). In 2019, tuna fisheries accounted for around 5.7 million metric tons (MT) globally (6.3 % of reported global landed volume from marine capture fisheries [65] corresponding to $11.7 billion in first sales and an end value of $40.8 billion [66]. The Pacific Ocean is the largest contributor to global tuna landings (3.4 million MT; 65 % – the bulk being skipjack) and accounts for 64 % of end value [66]. This is driven by favorable environmental conditions (i.e., temperature and hydrology) for multiple tuna species [67], as well as the relative geographic proximity to fishing grounds for certain fishing nations [68,69], and material conditions enabling fishing and business more generally (e.g., presence of key infrastructure, favorable socio-political climate, possibility to set up businesses, etc.) [54].

Two Regional Fisheries Management Organizations (RFMOs) regulate tuna fisheries in the Pacific Ocean: the Western and Central Pacific Fisheries Commission (WCPFC) [70] and the Inter-American Tropical Tuna Commission (IATTC) [71]. The WCPFC manages stocks from Japan to Australia, through Southeast Asia and the Pacific Islands, while the IATTC manages stocks in the Eastern Pacific Ocean (EPO). Tuna catches in the EPO have steadily increased since the 1950s, reaching 662,800 metric tons in 2022 for the three main species (yellowfin, skipjack, and bigeye tuna), representing approximately 13 % of global tuna catch [72]. Domestic-flagged industrial purse seiners account for over 90 % of the region's landings [24].

In Sections 3.1 to 3.3 we identify and describe the direct and ultimate owners of 1648 registered tuna fishing vessels operating within the EPO, a sample representing ca. 92 % of registered IATTC vessels $\geq$ 20 m (see further). Our analysis focuses on assessing the extent of foreign ownership in the tuna fishing industry, based on the premise that analysis at the flag state level may not accurately reflect a country's real fishing presence or dominance since vessels may be effectively owned or controlled by other countries through corporate ownership. We examine the number of vessels and gross tonnage at three levels (flag state, country of the direct owner, and country of the ultimate owner) to determine how ownership by foreign companies in the Global North might be underestimated when only considering flag states (which is the common level of analysis, e.g., [1,2,14]). In Section 3.4 we analyze spatial fishing effort for a subsample of 595 fishing vessels, representing all vessels in the sample for which spatial information was available in the Global Fishing Watch database in 2020 [73], and for which fishing

hours > 0 (see further). We analyze the magnitude and distribution of fishing effort (measured in hours fished), focusing on effort allocated within the EEZs of coastal states in the Global South. Finally, we reflect on what our findings mean for the sustainable and equitable management of tuna fisheries.

2. Methods

2.1. Study area and sample

The study area is defined by the boundaries of the Convention Area of the IATTC [71] (Fig. 1) which encompasses 19 EEZs, of 15 countries: Canada, the United States of America (USA), Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, Chile, France, and the United Kingdom[1].

We define the vessel population of interest by their authorization to fish for tunas within this jurisdiction (EEZs and high seas), reflected by their presence in the IATTC's Regional Vessel Register (RVR) [74]. In 2022, 4425 tuna vessels were authorized to fish. We then narrowed down our scope by focusing on vessels measuring at least 20 m in length (1794 vessels). The commonly used threshold of ≥ 24 m (e.g., [75]) was considered too strict for our purposes since it would exclude many semi-industrial vessels representing significant proportions of fleets in certain countries.[2] However, due to substantial gaps in ownership data, it was necessary to define a representative sample. The sample was restricted by the availability of ownership data in the Orbis database needed for corporate ownership analysis (1648 vessels). Table 2 provides an overview of the relative sample sizes across different countries.

We classified owners' countries as 'Global North' (GN) or 'Global South' (GS) based on several criteria: Human Development Index (HDI) [76], World Bank classification of income [77], geographical position in reference to the Brandt line [78], and membership of economic and political alliances (G7, G20, G77, and BRICS) (Table 1). While these categories provide a useful framework, it is important to recognize that they are not absolute. China's position is ambiguous; here it is considered part of the GN related to its vast and diverse domestic seafood market and dominant position in global industrial capture fisheries [14, 17].

Technical vessel data (length gross tonnage, engine power) were sourced from the IATTC's RVR. Data on engine power were missing for 160 vessels in the sample (<10 %) and 362 vessels in the population (ca. 8 %), while data on gross tonnage were missing for 11 vessels in the sample (<1 %) and 88 vessels in the population (<2 %).

2.2. Ownership analysis

The main source for ownership data was the Orbis database, compiled and managed by Bureau van Dijk [79]. Ownership data are collected through a country's Ministry of Commerce in jurisdictions where ownership disclosure is mandatory,[3] or otherwise from associated data providers, or directly from the companies themselves [80]. Ownership information is regularly updated and subjected to rigorous quality control. Marine vessel information is kept up to date based on information from IHS Markit (a subsidiary of S&P Global).

We extracted data (June 2022)[4] on the owning entity's name, unique ID number ('BvD ID number'), and country of registration, at two hierarchical levels: the Immediate Shareholder (ISH) and the Global Ultimate Owner (GUO) (detailed explanation below). See Table S1 in Supplementary Materials (S) for all variables collected.

Our method for ownership analysis involves the bottom-up identification of shareholders and ultimate owners along a hierarchical ownership path that begins with the fishing vessel (Fig. 2). We focus on two default hierarchical levels provided by Orbis: the Immediate Shareholder (ISH) and the Global Ultimate Owner (GUO). The GUO sits highest in the hierarchy, while the ISH (direct owner) sits lowest. Consistent with the International Financial Reporting Standards (IFRS) definition of controlling shareholders, we define the GUO at the 50.01 % threshold, whereby every hierarchical layer corresponds to minimum 50.01 % ownership (see Fig. S1 for parameterization).

The International Maritime Organization (IMO) attributes permanent marine vessel identifiers which stay with the vessel until it is scrapped [81]. Vessel IMO numbers can be queried directly in the Orbis database. The IMO number thus provides a link between the vessel and its direct owner in Orbis, and from there to its subsequent shareholders at different hierarchical levels. In the absence of an IMO number (or when no match was found in Orbis), we attempted to identify the vessel owner's BvD ID number in Orbis based on owner information included in the RVR (company name and address). Failing this, we use the original text data included in the RVR and assume that the ISH and the GUO are the same entity. This decision diagram is summarized in Figure S2.

We made differences in data quality explicit by attributing simple confidence scores to the ownership data (Table S2). Our method identified corporate actors with a high degree of confidence for almost 80 % of sampled vessels, and for ca. 97 % of vessels corporate actors could be identified with a medium to high degree of confidence. Confidence scores are high across gear types, albeit slightly lower for recreational fishing, harpoon, and multi-purpose vessels (Table S3).

2.3. Spatial analysis of fishing activity

We used Automatic Identification System (AIS) derived spatial fishing effort data from Global Fishing Watch (GFW) [73] (0.1° resolution) to study the distribution of fishing effort (fishing hours) by fishing companies in our sample and their respective countries of registration. GFW's Fishing Effort dataset includes, for the year 2020, the daily positions and suspected fishing activity of fishing vessels around the globe[5]. We first subsetted the GFW dataset using a shapefile of the IATTC Convention Area (https://ckan-bluebridge.d4science.org), which yielded a set of 873 vessels for which fishing hours > 0 according to GFW data. Of these, 595 were identified as tuna fishing vessels by cross-referencing the Maritime Mobile Service Identity (MMSI) numbers in the GFW database with those in our ownership dataset. In this paper, when we mention a country's 'registered fishing hours', we refer to the fishing hours recorded by GFW – thereby not always explicitly stating that this is based on a subsample (see Table 2 for coverage).

To study fishing companies' activities within coastal state EEZs, we added an EEZ category to each coordinate by overlaying the GFW data with EEZ shapefiles (https://marineregions.org). We conducted data visualization (spatial mapping) and spatial effort analysis, in R Studio (version 2022.02.3+492) using packages 'rgdal', 'rgeos', 'sp', 'sf' and 'leaflet'.

[1] Chile and Ecuador have separate EEZs for certain islands within their territories: Easter Island (Chile), San Felix Island (Chile), and the Galapagos Islands (Ecuador). French territories include French Polynesia and Clipperton Island, and the Pitcairn Islands are an Overseas Territory of the United Kingdom.

[2] For example, semi-industrial longline vessels [19–23] m represent large proportions of IATTC registered longline fleets in Mexico and the United States (55 % and 59 % respectively). The impact on the sample size is furthermore significant, as a total of 307 vessels would have been excluded from the sample if the more stringent criterion had been used (of these, ca. 80 % were longline vessels).

[3] This furthermore depends on company size, status (i.e., listed/unlisted), and ownership percentage.

[4] While ownership data from 2020 were preferred, Orbis does not store historical ownership data, limiting us to the data available at the time of study.

[5] We refer to https://globalfishingwatch.org/data-download/datasets/public-fishing-effort (accessed 14/04/2024) and [73] for a detailed description of the data.

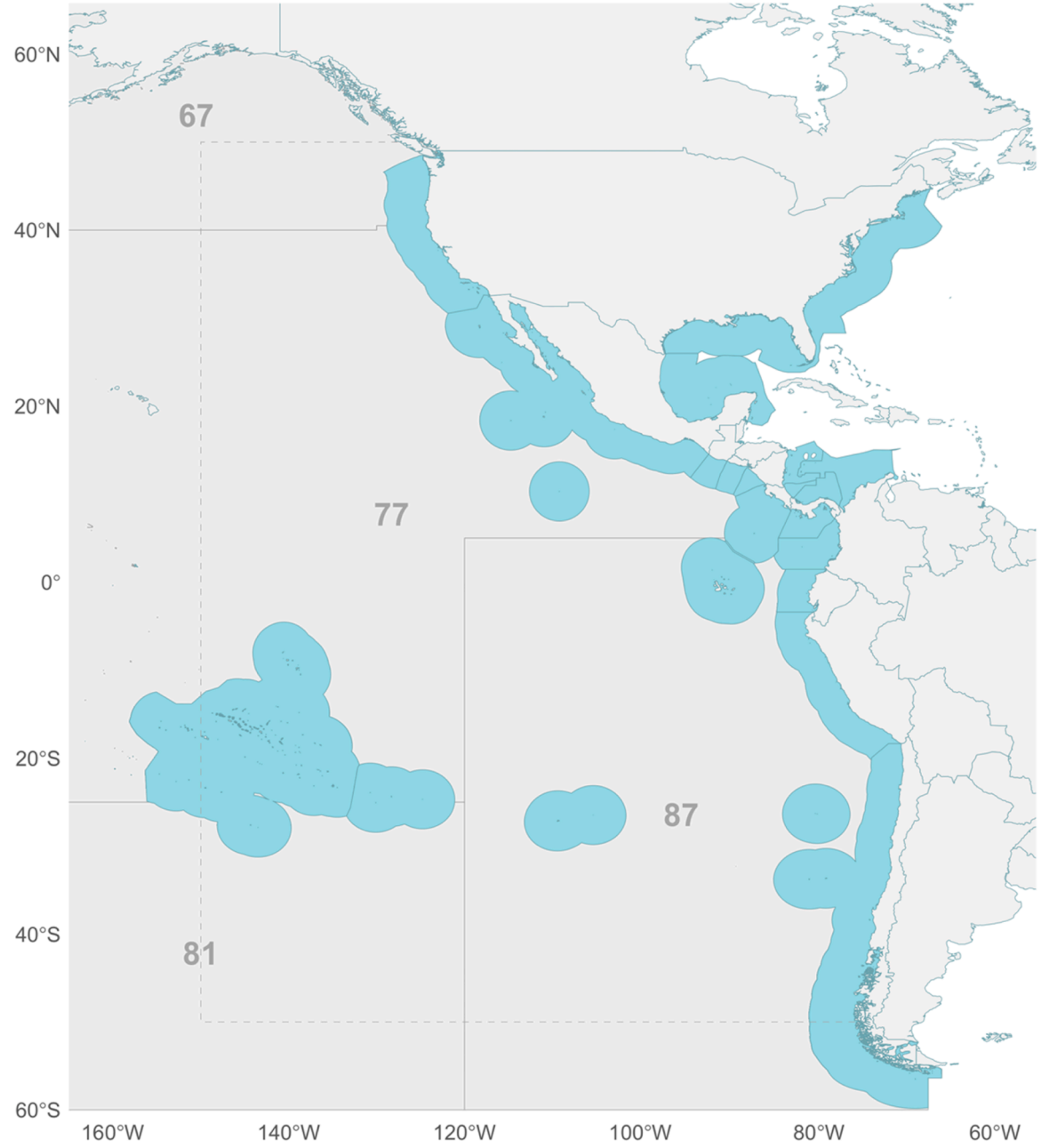


Fig. 1. IATTC Convention Area map (dotted lines), with indication of country EEZs and FAO Major Fishing Areas 67, 77, 81, and 87 (solid lines).

3. Results

3.1. Sample description

In 2022, 4,425 tuna vessels were authorized to fish, flagged to 24 countries. Longline and purse seine are the dominant gear types, together accounting for 92.2% of engine power and 94.3% of gross tonnage. We analyzed direct and ultimate ownership for 1,648 vessels, corresponding to 37.2% of the population, but 91.9% of vessels ≥ 20 m (hereafter referred to as 'the subset') (Table 2). For each flag country, the sample covers on average 91.1 % of vessels ≥ 20 m (SD=15.1). Taiwan (63.8 % of the subset), Ecuador (63.6 %), and Chile (50.0 %) have a comparatively lower coverage.

The sample captures 71.8 % of identifiable fishing capacity in the IATTC management area in terms of engine power, and 90.4 % in terms of gross tonnage (GT). Coverage of GT in the sample is not representative for Canada (26.6 %), Costa Rica (9.6 %) and Chile (0.9 %), and is also comparatively low for France and USA is (74.1 % and 62.1 %, respectively). The sample covers 97.9 % of GT in the ≥ 20 m subset, with lowest coverage for Taiwan (89.7 %), Costa Rica (72.5 %), and Chile (67.0 %).

3.2. Scratching the surface: sampled tuna vessels by flag state and continent

Registered semi-industrial and industrial tuna fishing vessels in the sample were predominantly flagged to China (398 vessels), USA (219), Japan (203), Mexico (187), Ecuador (119) and South Korea (99), composing 74.3 % of our sample. The sample captured 1240 longline vessels (LL) (81.1 %), 264 purse seiners (PS) (9.5 %), 50 pole-and-line vessels (3.2 %), 45 trollers (2.9 %), and 'other' vessels making up 3.2 % (Table 3).

The sampled Asian, European, and Oceanian vessels consisted predominantly of longline vessels (94.1 %, 97.7 %, and 100 %,

Table 1
Classification of countries into 'Global North' and 'Global South', based on multiple criteria (HDI, income category, membership in economic alliances, and position relative to the Brandt line). HIC = High Income Country, UMIC = Upper Middle-Income Country, LMIC = Lower Middle-Income Country; (*) The European Union is a full member of G20, alongside three of its Member States: France, Germany, and Italy. Spain is a permanent guest. The EU is a "non-enumerated" member of the G7; (**) The position of Taiwan is contested, and depending on the source, may or may not be considered part of China; (***) Norway is a G20 guest country in 2024.

Continent	Country	HDI	Income cat.	Alliances	Position to Brandt line	Classification
Asia	China	High	HIC	BRICS, G20, G77	Below	GN
	Japan	Very High	HIC	G7, G20	Above	GN
	South Korea	Very High	HIC	G20	Above	GN
	Taiwan	Very High	HIC	n.a.**	Below	GN
	Russian Federation	Very High	UMIC	BRICS, G20	Above	GN
	Thailand	Very High	UMIC	G77.	Below	GS
	Oman	Very High	HIC	G77	Below	GS
Europe	Spain	Very High	HIC	G7, G20*	Above	GN
	France	Very High	HIC	G7, G20*	Above	GN
	Portugal	Very High	HIC	G7, G20*	Above	GN
	Netherlands	Very High	HIC	G7, G20*	Above	GN
	Italy	Very High	HIC	G7, G20*	Above	GN
	Norway	Very High	HIC	n.a.***	Above	GN
	Lithuania	Very High	HIC	G7, G20*	Above	GN
	Germany	Very High	HIC	G7, G20*	Above	GN
North America	USA	Very High	HIC	G7, G20	Above	GN
	Canada	Very High	HIC	G7, G20	Above	GN
LAC	Mexico	High	HIC	G20	Below	GS
	Ecuador	High	UMIC	G77	Below	GS
	Panama	Very High	HIC	G77	Below	GS
	Venezuela	Medium	UMIC	G77	Below	GS
	Peru	High	UMIC	G77	Below	GS
	Colombia	High	HIC	G77	Below	GS
	Costa Rica	Very High	HIC	G77	Below	GS
	El Salvador	Medium	UMIC	G77	Below	GS
	Nicaragua	Medium	UMIC	G77	Below	GS
	Belize	High	UMIC	G77	Below	GS
	Chile	Very High	HIC	G77	Below	GS
Oceania	Vanuatu	Medium	LMIC	G77	Below	GS
Africa	Equatorial Guinea	Medium	UMIC	G77	Below	GS

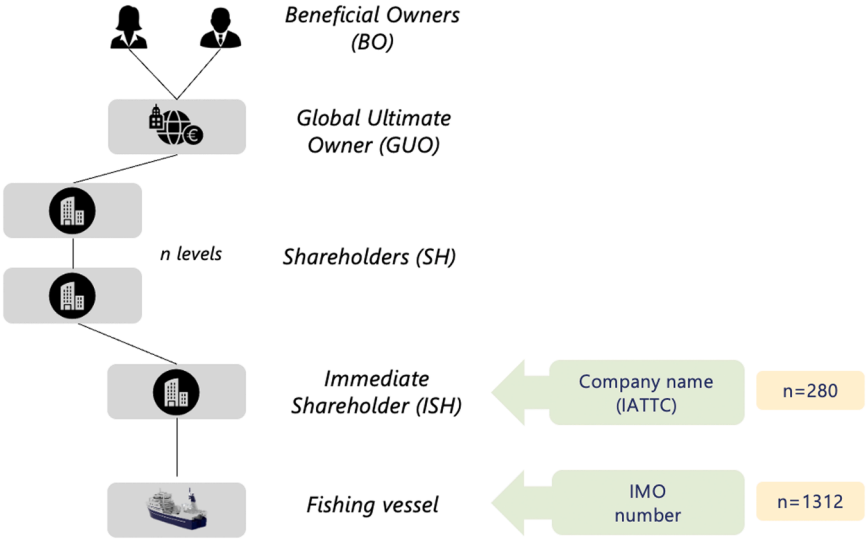


Fig. 2. Conceptual framework and entry points to the bottom-up extraction protocol. For 1312 vessels (80 % of the sample) the IMO number provided the entry point to the protocol, while a workaround via the RVR was applied for 280 vessels (17 %). For the remaining 56 vessels in the sample, there was no entry point to the extraction protocol (see Table S2).

respectively), while the Latin American and Caribbean (LAC) vessels in the sample consisted mainly of LL (60.4 %), and PS (39.3 %; mainly flagged to Ecuador and Mexico). Compared to other regions, the sampled North American vessels had a greater variety of gear types, with longline (51.1 %) and troll (19.1 %) being the most prevalent.

Considering fleet capacity, sampled registered tuna vessels flagged to

Table 2
Sample coverage in terms of registered vessel numbers. Number of vessels by flag country, in respectively (1) the population (all vessels present in the IATTC RVR in 2022; n=4425), (2) a subset of vessels ≥ 20 m (n=1794), (3) the sample of vessels selected for ownership analysis, and (4) a subsample for which registered fishing hours > 0 in 2023 according to GFW data (n=595).

Flag country	Population	Subset (≥ 20 m)	Sample	% of Subset	% of Population	Spatial subsample	% of Population	% of Subset	% of Sample
USA	1313	229	219	95.6	16.7	83	6.3	36.2	37.9
Chile	651	2	1	50.0	0.2	0	NA	NA	NA
China	399	398	398	100	99.7	153	38.3	38.4	38.4
Costa Rica	295	10	7	70.0	2.4	0	NA	NA	NA
Mexico	257	199	187	94.0	72.8	21	8.2	10.6	11.2
Canada	251	18	16	88.9	6.4	5	2.0	27.8	31.3
Ecuador	205	187	119	63.6	58.0	53	25.9	28.3	44.5
Japan	204	204	203	99.5	99.5	45	22.1	22.1	22.2
Panama	170	58	58	100.0	34.1	9	5.3	15.5	15.5
Taiwan	127	127	81	63.8	63.8	61	48.0	48.0	75.3
Guatemala	102	0	0	NA	NA	0	NA	NA	NA
South Korea	99	99	99	100	100	56	56.6	56.6	56.6
Spain	91	91	91	100	100	36	39.6	39.6	39.6
France	76	36	36	100	47.4	5	6.6	13.9	13.9
Vanuatu	53	53	53	100	100	35	66.0	66.0	66.0
Nicaragua	53	8	6	75.0	11.3	0	NA	NA	NA
Venezuela	21	21	20	95.2	95.2	10	47.6	47.6	50.0
Peru	18	18	18	100	100	8	44.4	44.4	44.4
Colombia	14	14	14	100	100	9	64.3	64.3	64.3
Portugal	11	11	11	100	100	3	27.3	27.3	27.3
El Salvador	11	7	7	100	63.6	3	27.3	42.9	42.9
Germany	2	2	2	100	100	0	NA	NA	NA
Lithuania	1	1	1	100	100	0	NA	NA	NA
Belize	1	1	1	100	100	0	NA	NA	NA
Total	**4425**	**1794**	**1648**	**91.9**	**37.2**	**595**	**13.4**	**33.2**	**36.1**

Table 3
Distribution of gear types in the sample, by flag country and continent (n=1648). 'Other' constitutes recreational fishing, multi-purpose, trawler, and harpoon.

Continent	Vessel flag	LL	PS	Pole and line	Troll	Other	Total
Asia	China	398					398
	Japan	165		38			203
	South Korea	99					99
	Taiwan	81					81
	Asia total	**743**		**38**			**781**
Europe	Spain	88	3				91
	France	36					36
	Portugal	11					11
	Germany	1				1	2
	Lithuania					1	1
	Europe total	**136**	**3**			**2**	**141**
LAC	Mexico	122	57	8			187
	Ecuador	12	107				119
	Panama	39	19				58
	Venezuela		20				20
	Peru	2	16				18
	Colombia		14				14
	Costa Rica	7					7
	El Salvador	4	3				7
	Nicaragua		6				6
	Belize	1					1
	Chile	1					1
	LAC total	**188**	**242**	**8**			**438**
North America	USA	120	19	4	29	47	219
	Canada				16		16
	North America total	**120**	**19**	**4**	**45**	**47**	**235**
Oceania	Vanuatu	53					53
	Oceania total	**53**					**53**
Total		**1240**	**264**	**50**	**45**	**49**	**1648**

Asian countries account for 43.2 % of engine power and 43.7 % of gross tonnage[6]; China captured 20.9 % and 22.5 %, respectively (Table 4). The sampled LAC vessels captured 36.6 % of combined engine power and 37.4 % of tonnage, dominated by Mexico and Ecuador. The European fleet accounted for 7.2 % and 9.3 % of engine power and gross tonnage in the sample, dominated by Spain which contributed 64.5 % of EU-flagged vessels, 58.0 % of engine power, and 61.1 % of gross tonnage.

The sample of 1648 vessels followed a similar pattern as the subset of 1794 vessels ≥ 20 m, confirming that findings could be generalized to describe ownership trends of registered industrial and semi-industrial fishing vessels in the IATTC management area, albeit with caution. LL and PS fleets represented the bulk of vessels (91.3 % of the sample and 91.2 % of vessels ≥ 20 m in the population).

3.3. Beyond the flag state: who are the direct owners of (semi-) industrial tuna fishing vessels registered in the EPO?

Analysis showed that 822 companies directly owned the 1648 fishing vessels in our sample[7], (i.e., 2.0 vessels per company on average [SD=2.9]). Companies holding LL (2.3 ± 3.3 vessels) and PS vessels (1.7 ± 2.2) owned most vessels per company. Chinese and South Korean ISHs owned the most fishing vessels: 7.2 vessels (SD=6.6), and 7.1 vessels (SD=6.7), respectively while ISHs registered in Taiwan, Spain and the USA owned the lowest number of vessels (1.1, with respective SDs of 0.4, 0.4 and 0.6) (Fig. 3).

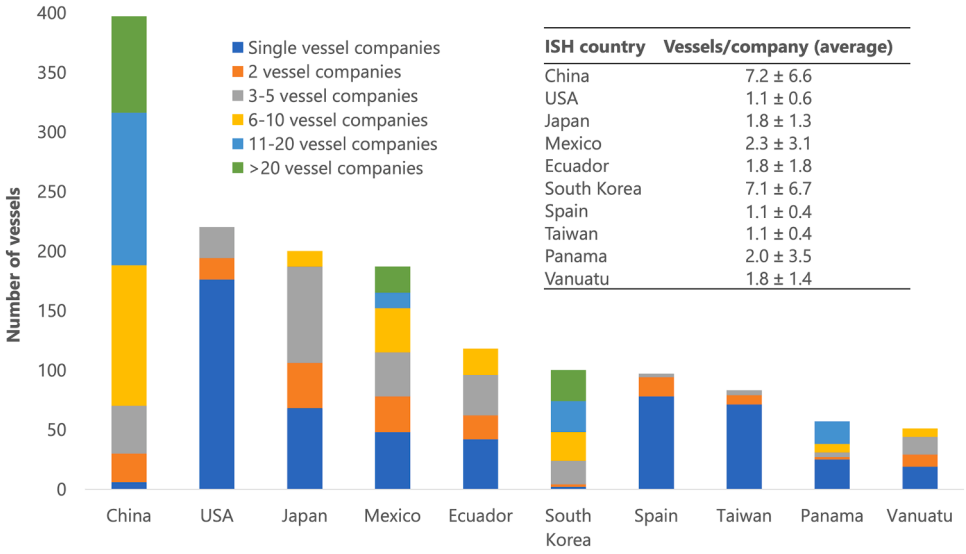
Most vessels in the sample (1047; 63.5 %) were owned by multi-vessel fishing companies. The highest number of single vessel companies was found in the USA (n=220), while their relative presence was highest for Taiwan (86.0 % of sampled Taiwanese vessels at the ISH

[6] Gross tonnage data were available in the IATTC RVR for >99 % of sampled vessels, while engine power data were available for >90 % of sampled vessels (see Section 2.1).

[7] LL: 544 entities owning 1240 vessels, PS: 151 entities owning 264 vessels, pole and line: 38 entities owning 50 vessels, troll: 44 entities owning 48 vessels, trawl: 2 entities owning two vessels, harpoon: 1 entity owning 1 vessel, recreational fishing: 25 entities owning 26 vessels.

Table 4
Sample description in terms of number of vessels, engine power and gross tonnage, by continent and flag country. Note that these are approximations given that data on engine power and gross tonnage were lacking for 160 (<10 %) and 11 (<1 %) vessels in the sample, respectively (see Section 2.1).

Continent	Vessel flag	No. vessels	%	Engine power (hp)	%	Gross tonnage (mt)	%
Asia	China	398	24.2	378,732	20.9	172,955	22.5
	Japan	203	12.3	188,964	10.4	82,992	10.8
	South Korea	99	6.0	114,000	6.3	40,485	5.3
	Taiwan	81	4.9	102,040	5.6	39,753	5.2
	Asia total	**781**	**47.4**	**783,736**	**43.2**	**336,185**	**43.7**
Europe	Spain	91	5.5	75,631	4.2	44,089	5.7
	France	36	2.2	19,062	1.1	4520	0.6
	Portugal	11	0.7	10,075	0.6	4667	0.6
	Germany	2	0.1	12,348	0.7	9347	1.2
	Lithuania	1	0.1	13,379	0.7	9499	1.2
	Europe total	**141**	**8.6**	**130,495**	**7.2**	**72,122**	**9.4**
LAC	Mexico	187	11.3	184,337	10.2	80,386	10.4
	Ecuador	119	7.2	241,560	13.3	104,617	13.6
	Panama	58	3.5	85,678	4.7	35,850	4.7
	Venezuela	20	1.2	43,416	2.4	27,190	3.5
	Peru	18	1.1	24,620	1.4	8630	1.1
	Colombia	14	0.8	39,545	2.2	15,078	2.0
	Costa Rica	7	0.4	2975	0.2	623	0.1
	El Salvador	7	0.4	18,523	1.0	7441	1.0
	Nicaragua	6	0.4	21,750	1.2	7956	1.0
	Belize	1	0.1	1217	0.1	353	0.0
	Chile	1	0.1	520	0.0	144	0.0
	LAC total	**438**	**26.6**	**664,141**	**36.6**	**288,268**	**37.4**
North America	USA	219	13.3	174,670	9.6	44,913	5.8
	Canada	16	1.0	8643	0.5	2056	0.3
	North America total	**235**	**14.3**	**183,313**	**10.1**	**46,969**	**6.1**
Oceania	Vanuatu	53	3.2	52,800	2.9	26,264	3.4
	Oceania total	**53**	**3.2**	**52,800**	**2.9**	**26,264**	**3.4**
Total		**1648**	**100.0**	**1814,485**	**100.0**	**769,808**	**100.0**



ISH country	Vessels/company (average)
China	7.2 ± 6.6
USA	1.1 ± 0.6
Japan	1.8 ± 1.3
Mexico	2.3 ± 3.1
Ecuador	1.8 ± 1.8
South Korea	7.1 ± 6.7
Spain	1.1 ± 0.4
Taiwan	1.1 ± 0.4
Panama	2.0 ± 3.5
Vanuatu	1.8 ± 1.4

Fig. 3. Distribution of vessels in multi-vessel companies, by ISH country. Only the top 10 ISH countries are displayed.

level), Spain (80.0 %), and the USA (80.0 %). However, it is important to note that coverage of Taiwanese vessels is comparatively low, with 63.8 % of registered Taiwanese vessels ≥ 20 m included in the sample (Table 2). In total, 326 vessels (19.8 %) were owned by companies owning 10 or more vessels. Of these, 64.1 % (n=209) were owned by Chinese companies, followed by South Korean (n=52, 16.0 %), and Mexican companies (n=35, 10.7 %). For China, this furthermore corresponded to 52.6 % of all Chinese-owned vessels in the sample (82.4 % including > 5 vessel firms). Conversely, ISHs registered in other major DWF nations like Taiwan and Spain mostly owned one vessel (93.4 % and 89.7 % of companies, respectively).

The country of registration of the direct owner (ISH) was different from the flag of the vessel(s) it owned in 2 % of cases (n=38 vessels) (Fig. 4). Yet, for some flag countries, the shift is noteworthy. Of vessels flagged to Panama, 19 % were owned by ISH entities in another country (mainly Belize, Ecuador, Spain), while 83 % of Nicaraguan vessels were held by foreign entities in Panama and Spain.

Of the 10 largest companies in terms of vessel numbers, seven were registered in China, one in South Korea, one in Panama and one in Mexico (Table S4). Nine were companies operating LL vessels. The top 10 PS companies were registered in LAC countries and jointly captured 33.0 % of PS and 34.9 % of engine power (Table S5).

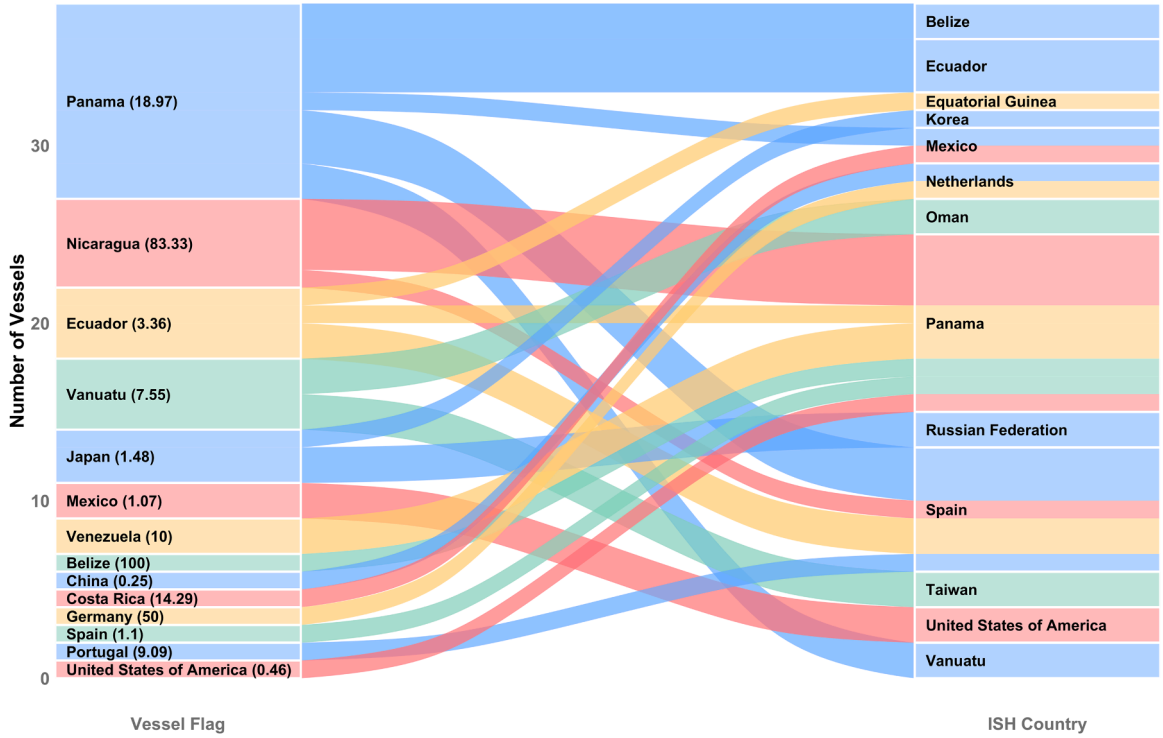


Fig. 4. Alluvial plot indicating the shift in country of registration between the first (vessel flag) and the second analytical level (ISH). Only deviations are included in the figure (n=38 vessels) – for 98 % of vessels the flag country and the country of registration of the ISH are the same. Numbers on the left indicate, for each flag country, the percentage of vessels for which ISH country ≠ flag country. Countries on the left are sorted by absolute vessel numbers (high to low), countries on the right are ranked in alphabetical order.

3.4. Digging deeper: who are the ultimate owners of (semi-) industrial tuna fishing vessels registered in the EPO?

On average, the 766 GUOs identified owned 2.2 vessels (a small increase compared to the ISH level). For 259 vessels (16 %), the GUO was a company not previously identified at ISH level. For 12 % of these vessels (n=31), the GUO was registered in a country other than the ISH. Among sampled GUOs, those registered in China and South Korea owned the largest fleets (respectively 8.5 ± 7.4 and 7.7 ± 7.0 vessels on average). Total gross tonnage held by each GUO and by GUO country was distributed unequally (Gini coëfficient of 0.670 and 0.668, respectively); ca. 25 % of GUOs owned 75 % of gross tonnage (Fig. S3).

Fig. 5 summarizes the shifts in country of registration across the three levels of analysis (flag country, ISH, and GUO). A total of 102 vessels (6 % of the sample) were ultimately owned by foreign companies, with the majority owned by GUOs in the Global North (79 vessels; 78 %). Slightly more than half of the latter were flagged to countries in the Global South (42 vessels; 53 %); mainly to LAC countries (23 vessels; mostly Ecuador and Panama) and to Vanuatu (19 vessels). Vanuatu, Panama, and Ecuador occur in the ownership structure of 54 vessels for which a country shift is observed (53 %), either as flag country, ISH country, or both. Overall, Panama and Vanuatu, known flags of convenience and tax havens [52,82], appear in the ownership structure of 136 vessels in the sample (8 %), at any of the three levels studied.

Noteworthy shifts compared to analysis at the ISH level include the concentration by seven Taiwanese GUOs of 40 LL vessels, flagged to China (25 vessels, owned by three Chinese ISHs) and Vanuatu (15 vessels, owned by four Vanuatuan ISHs). Through corporate ownership, the Taiwanese companies in the sample effectively increased their combined *de facto* LL fleets to 123 vessels (+48 % compared to analysis at the ISH level) (Table S6). Similarly, sampled Spanish GUOs encapsulated five LL vessels from Portuguese and Ecuadorian ISHs (+6 %) and eight PS (+89 %) from ISHs registered in Ecuador, El Salvador, and Panama (see Table S7 and Table S8 for company identities).

3.5. Spatial analysis of fishing activity by GUOs

Spatial fishing data were available in the GFW database for 595 vessels (36 % of sampled vessels) (see Table 2 for coverage by flag country). Coverage in terms of GUO country was 42 % for Spain (45 vessels), 40 % for China (148) and 56 % for South Korea (56) (Table S9). Coverage was high for certain GUOs (>70 % of vessels in the corporate group).[8]

Most fishing nations operated across extensive areas within the IATTC Convention Area, covering a total surface of 54.3 million km^2 (ca. 80 % of the entire area). Based on the subsample, we identified China as the GUO country spanning the largest area (25.5 million km^2), followed by Spain (21.1 million km^2), and Ecuador (21.0 million km^2). Fishing activity hotspots are found at the intersection of FAO 77 and FAO 87 (North) – notably the area east of French Polynesia's EEZ and north of Pitcairn Islands EEZ, and from there east into FAO 87 (North) (Fig. 6, Fig. S4). This coincides with the hotspots for most Asian countries, whereas for vessels ultimately owned by Spanish GUOs, waters off the Peruvian and Chilean coast provide the most important fishing grounds.

Most of the sub-sampled tuna fishing vessels' registered fishing hours within the IATTC Convention Area were concentrated in the high seas (94 %), reaching more than 99 % for China, Taiwan, South Korea, Japan, and Vanuatu. Spanish GUOs allocated around three percent of their combined fishing hours within the EEZs of Global South countries surrounding the IATTC management area. Other countries with a comparatively higher reliance on the 19 EEZs of interest were Mexico

[8] E.g., 'Pingtairong Ocean Fishery' (China) (74 %), 'Organización Pinsa SA de CV' (Mexico) (73 %), 'Qingdao Furui Fishery Co., Ltd.' (China) (77 %), 'Corporación Real Corprealsa S.A.' (Ecuador) (91 %), 'McAdam's Fish LLC' (USA) (91 %), and 'Zhejiang Ocean Fisheries Group Co., Ltd.' (China) (73 %).

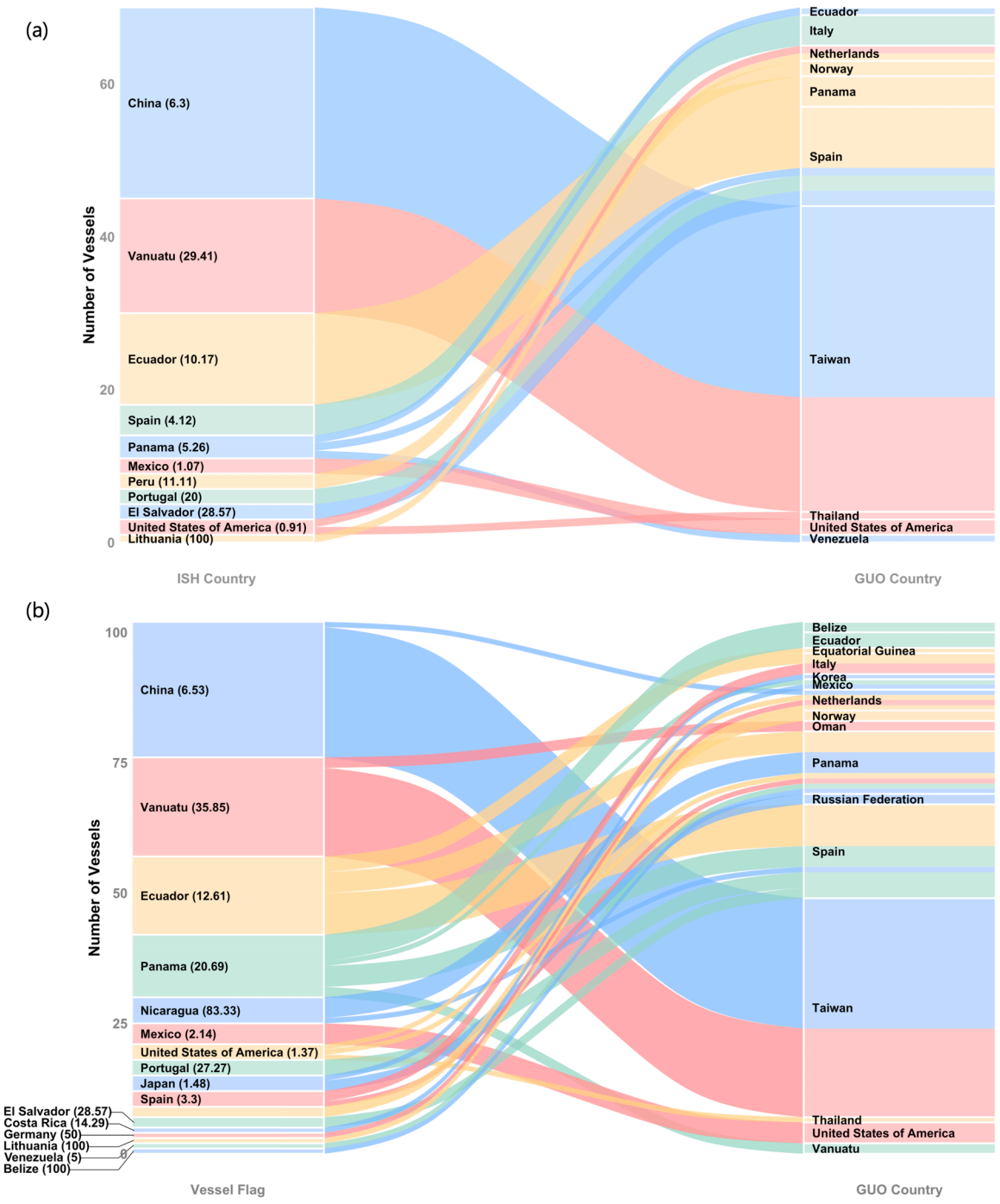


Fig. 5. Alluvial plots indicating the shift in country of registration between (a) the second (ISH) and the third analytical level (GUO) and (b) the first (Flag country) and the third analytical level (GUO). Only deviations are included in the figure (n=70 vessels in plot a, n=120 in plot b). Numbers on the left indicate, for each ISH (Flag) country, the percentage of vessels for which ISH (Flag) country ≠ GUO country. Countries on the left are sorted by absolute vessel numbers (high to low), countries on the right are ranked in alphabetical order.

(43 %), Ecuador (32 %), Panama (32 %), Venezuela (31 %), and USA (28 %). Most companies registered in these countries fished mainly in their own EEZs, but some were also active in the EEZs of neighboring countries (e.g., 21 % of Ecuador's registered within-EEZ activity at the GUO level took place inside the Peruvian EEZ).

Among the 19 EEZs studied, the highest fishing effort was concentrated in the Mexican EEZ, the Galapagos Islands EEZ, and the EEZ of French Polynesia (Table 5). Mexican GUOs accounted for 96.5 % of fishing activity in the Mexican EEZ, while French GUOs accounted for 100 % of fishing activity in the EEZ of French Polynesia. In 2020, GUO companies fishing in the Galapagos Islands EEZ dedicated an average of 20.0 % (SD=23.1) of their total fishing hours in the IATTC Convention Area to this zone, highlighting its importance. Ecuadorian GUOs were responsible for 78.6 % of effort in the Galapagos Islands EEZ. Companies in Panama (12.5 %), Spain (3.4 %), Venezuela (3.3 %), and Equatorial Guinea (1.5 %) accounted for most of the remaining effort (Table S10). Ownership analysis reveals that companies registered to foreign countries operate under the Ecuadorian flag in this zone (Fig. 7), likely to circumvent Ecuadorian regulations that restrict fishing access to the EEZ to domestically registered vessels [83].

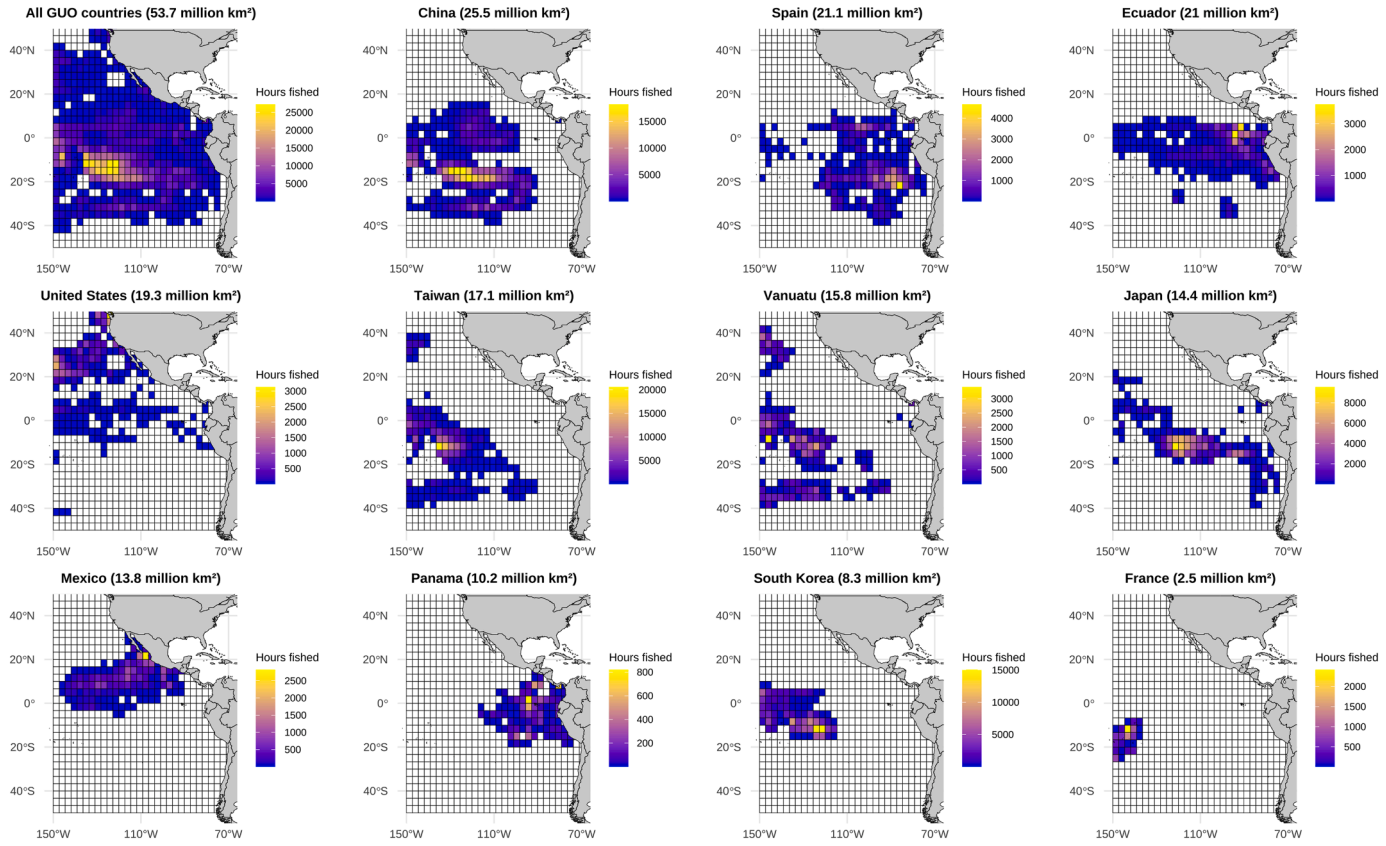


Fig. 6. Fishing activity hotspots in the IATTC Convention Area. This visualization highlights fishing activity hotspots (in hours fished) for top fishing countries in terms of vessel numbers. 'All GUO countries' aggregates data for these key countries. The analysis employs a 30x30 fishnet grid constructed over the area of interest using the WGS 84 coordinate reference system. Each cell aggregates fishing hours, calculated by spatially joining vessel locations (fishing hours >0) to the grid cells.

Table 5
Distribution of fishing effort (fished hours) within the IATTC Convention Area (EEZs and high seas). 'Unidentified' refers to coordinates for which no overlap was found with the EEZ and FAO shapefiles.

Zone	Fished hours	%
High Seas FAO 77	700,081	56.5
High Seas North FAO 87	274,696	22.2
High Seas Central FAO 87	153,575	12.4
High Seas FAO 81	39,542	3.2
Mexico EEZ	11,666	0.9
Galapagos EEZ (Ecuador)	11,139	0.9
French Polynesia EEZ (France)	10,343	0.8
Peru EEZ	10,164	0.8
US EEZ	6985	0.6
Canada EEZ	5861	0.5
Unidentified	4627	0.4
Panama EEZ	3252	0.3
Costa Rica EEZ	2411	0.2
Ecuador EEZ	1393	0.1
Colombia EEZ	1345	0.1
Clipperton EEZ (France)	1257	0.1
High Seas FAO 67	457	0.0
Nicaragua EEZ	43	0.0
Guatemala EEZ	36	0.0
Easter Island EEZ (Chile)	19	0.0
El Salvador EEZ	12	0.0
High Seas South FAO 87	7	0.0
Pitcairn Islands EEZ (UK)	1	0.0

4. Discussion

Revealing the nationality of corporate owners of registered tuna fishing vessels in the EPO at three analytical levels shows that flag state analysis underestimates the true scope of major fishing nations' tuna fisheries. In total, 102 vessels in our sample were ultimately owned by an entity registered in a country other than the flag country of the vessel, corresponding to 12 % of total engine power and 14 % of gross tonnage. For the PS fleet, this was 21 % and 22 %. For most vessels (65 %), the shift in country occurred at the GUO level, indicating that ownership analysis at the ISH level (the direct owner) similarly underestimates fleet capacity and ownership concentration. Indeed, the 25 largest GUOs (3 %) own 25 % of the registered vessels authorized to fish in the IATTC management area. Our finding of high concentration of ownership is in line with findings across a range of case studies [17,54,21,59,60,63,68,84] suggesting that concentration in industrial fishing fleets is commonplace and that global tuna value chains are increasingly interconnected and complex.

4.1. *The majority of (semi-) industrial tuna vessels in the EPO are owned by companies from the Global North*

Seventy-two percent of sampled IATTC registered (not confirmed active) EPO tuna vessels (n=1648) were ultimately owned by entities registered in the GN (65 % of GT). Dominant fishing nations (vessel flag) included China, USA, Japan, Mexico, Taiwan, Ecuador, Spain, and South Korea. A similar depiction was obtained when analyzing the entire population (n=4425). The dominance of China, Japan, Taiwan, Spain, and South Korea is consistent with the findings of other studies analyzing the distribution and ownership of global fishing effort [14,17,55,59,73]. In recent decades, Ecuador has emerged as a significant player in the tuna industry, solidifying its position as a major producer and exporter [68,85]. In 2018, it was the sixth largest producer of tuna globally, with landings of nearly 300,000 MT – an increase by 20 % compared to 2012 [66]. Mexico falls just outside the top ten [66,85].

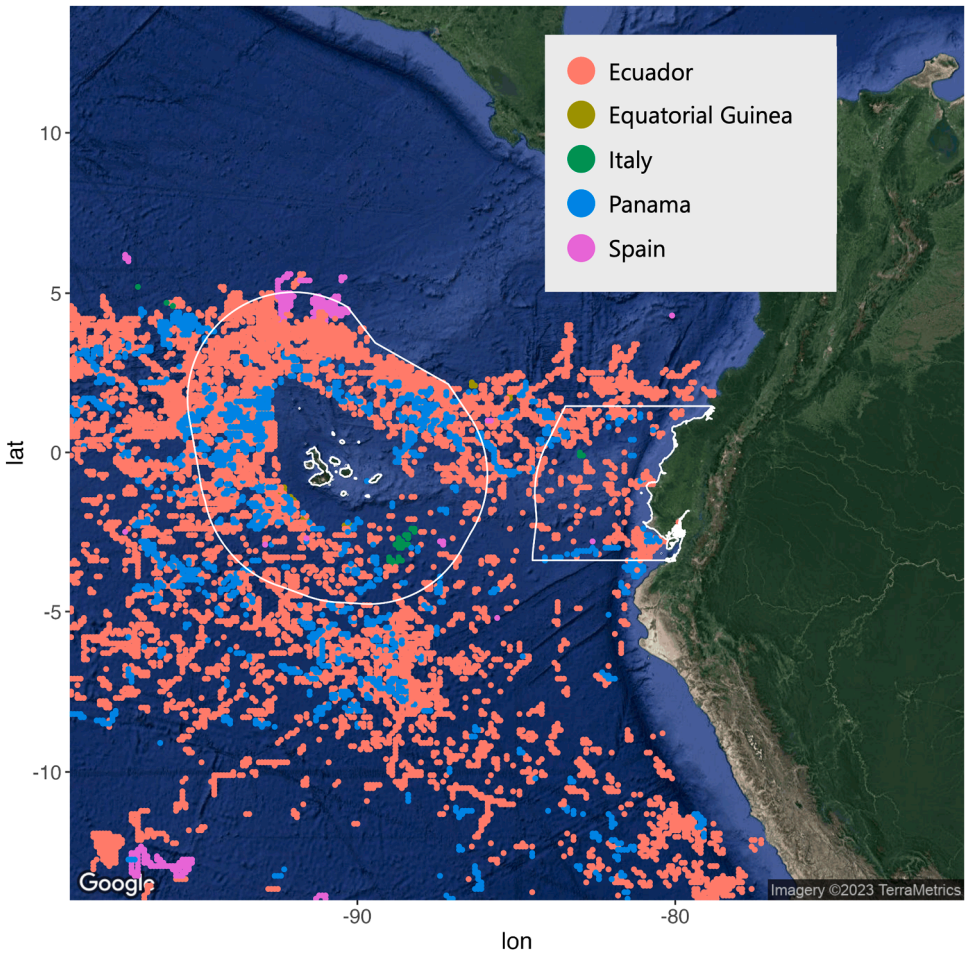


Fig. 7. Fishing nations' footprint (GUO level) in the Ecuadorian and Galpagos EEZs through operating fishing vessels flagged to Ecuador. Data points represent all coordinates with suspected fishing activity in 2020 (GFW) (resolution: 0.1°).

LAC countries, while comprising 41 % of authorized tuna vessels (29 % of vessels $\geq$ 20 m), accounted for 81 % of reported landings in 2021 [86]. This is due to the high proportion of PS, which account for almost 80 % of authorized LAC fleet capacity at the flag level. However, our results suggest that a significant share of these landings could be attributed to other countries, since the vessel flag differs from the nationality of the ultimate owner for about 17 % of purse seiners in our sample (28 % of gross tonnage).

The dominance of the PS fishery in the EPO (90 % of total tuna landings in 2021) [86] is further highlighted when examining the landings of major Asian fishing countries (>95 % LL). China, South Korea, Taiwan, and Japan, despite representing among the largest fleets in the RVR (Table 2), accounted for just 4 %, 1 %, 1 % and 1 % of reported tuna landings in 2021 (this was 44 %, 15 %, 13 %, and 10 % when only LL landings were considered). Notably, recent studies have highlighted significant illegal and/or unreported landings by Chinese vessels in the EPO, particularly involving sharks [87–89], underscoring the need for caution.

4.2. Vanuatu, Panama and Ecuador are hotspots for the incorporation of proxies

Our findings indicate that the oversight of corporate structure may lead to the inaccurate and inflated attribution of a substantial portion of fishing capacity (landings, benefit flows) to certain countries in the GS. By registering vessels in specific coastal states or jurisdictions known for tax advantages and lax regulatory oversight, fishing companies can gain access to key fishing grounds within those countries' EEZs while benefiting from tax breaks and other incentives [29,52]. Petrossian *et al.* [90] define flags of convenience (FoCs) as any flag other than that of the country where the registered owner is based. According to this definition, 19 % of sampled Panamanian vessels, and 8 % of Vanuatuan vessels in our sample constitute FoCs. Additionally, corporations may further enhance companies' benefits by establishing or acquiring subsidiary fishing or processing companies in such jurisdictions [54,91].

The use of FoCs enables vessel owners to minimize operational expenses, circumvent regulations related to the environment, insurance, labor, tax, and safety on board, while also providing a means to conceal their identities from law enforcement [92,93]. It may also allow fishing companies to access additional fisheries subsidies from various governments, which are important contributions for ensuring the economic viability of DWF endeavors [94,95]. Ford *et al.* [96] argue that the choice of FoC depends on the vessel owner's main concern: countries with strong legal systems (e.g., the Cayman Islands) are prioritized if the owner seeks protection from prosecution by their home country, whereas flags associated with limited regulatory oversight, high bank secrecy (e.g., Panama), and high levels of corruption (e.g., Equatorial Guinea) are preferred by owners involved in IUU fishing. A study conducted by the OECD [97] revealed that certain vessel registers, including Panama and Vanuatu, actively promote and facilitate owner anonymity, but pinpointed the corporate mechanisms *behind* these registers as the primary culprit responsible for concealing the identity of beneficial owners.

Panama is a desirable FoC for fishing corporations owing to its open registry and easy registration process, the possibility to engage foreign crew members, and a lack of adequate monitoring and enforcement [90,

98–100]. In our study, Panama's importance as a FoC is reflected in the relatively high proportion of vessels flagged to Panama which are not ultimately owned by Panamanian GUOs (20.7 %). In addition, Panama is a well-known offshore financial center and tax haven [52], allowing companies and their directors and owners to benefit from tax advantages, financial privacy, and ease of company formation. This estimate is likely conservative, as a significant portion of Panamanian GUOs may be effectively owned or controlled by beneficial owners (BOs) in the GN, but whose ownership links are undisclosed and therefore not accurately reflected in the Orbis database [80]. This is to some extent supported by the literature [60,92], and by clues found in Orbis (*Additional Reflections A* in Supplementary Materials (S)).

Another major FoC in our dataset is Vanuatu [82,101], owing to its fishing registry being open to owners of any nationality, the non-disclosure of beneficial ownership, the permission of corporate directors, the allowance of bearer shares (i.e., unregistered equity securities), and the absence of a government register of directors and/or shareholders (OECD, 2003). Our study confirmed Taiwanese ultimate owners for 17 Vanuatu-flagged tuna vessels (32 %). Vanuatu is also considered a notorious tax haven and offshore financial center [82], and given the lack of transparency around ownership, these figures are again likely an underestimate.

Gianni [102] reports an increase in fishing vessels flagged to Vanuatu and Panama following the deregistration and subsequent reflagging, in the early 2000s, of a large number of vessels suspected of IUU fishing, mainly from the registries of Belize and Honduras. This wave of de-registrations was the result of a series of measures taken by various RFMOs to improve oversight and control of open registries [103], and the buyback and scrap policy established by the Organization for the Promotion of Responsible Tuna Fishing (OPRT) to reduce the capacity of Japan's and Taiwan's LL fleets [68,103]. Miyake *et al.* [68] report the scrapping encompassed ca. 15 % of the total number of distant water LL at the time. The remaining ex-Japanese and Taiwanese IUU vessels were reflagged to third countries (Vanuatu, Seychelles, and others). Although effectively part of Vanuatu's national fleet, the literature suggests a strong footprint of DWF corporations from Taiwan behind Vanuatu-flagged fishing vessels [55,104]. According to the FAO [104], Asian vessels based in Port Vila operate under the Vanuatuan flag through joint ventures or other arrangements. Although we could not confirm the presence of Taiwanese-Vanuatuan joint ventures in our dataset, cross-referencing the data extracted from Orbis in 2022 with both newer and older Orbis data, as well as RFMO data, suggests that Taiwanese owners commonly use Vanuatu as an FoC and offshore center for hiding beneficial ownership (*Additional Reflections B* in S).

Finally, Ecuador was identified as a key country for DWF companies: 13 % of Ecuador-flagged vessels in our sample, and 24 % of tonnage, was ultimately owned by companies from Equatorial Guinea, Italy, Panama, and Spain. Ecuador does not allow access to its sovereign waters through bilateral access agreements with other countries [83]. Since 1991, Ecuador has required that foreign fishing companies wishing to obtain access work through Ecuadorian companies; either through lease agreements chartering Ecuadorian vessels or through association in joint ventures. In both cases, the vessels may operate only under the Ecuadorian flag within Ecuador's EEZ (mainland and insular). Through spatial analysis we have demonstrated that this is indeed the case, although fishing activity by foreign vessels flagged to Panama (n=4), Venezuela (n=3), Spain (n=2), the US (n=2), and Colombia (n=1) was detected. This likely constitutes illegal fishing, consistent with findings by Chinacalle-Martínez *et al.* [105] who reported illegal incursions by vessels flagged to at least 13 countries between 2012 and 2018 using GFW data. This is likely an underestimation, as recent findings by Paolo *et al.* [106] highlight. By combining satellite imagery, vessel GPS data, and deep-learning models, the study mapped industrial vessel activities and uncovered significant illegal incursions into the Galapagos Marine Reserve. Notably, the study detected an average of five vessels per week between 2017 and 2021 – vessels that were not publicly visible via AIS (see further).

Recent studies have found a strong link between foreign ownership, the use of FoCs and frequent reflagging of fishing vessels, and their increased risk of engagement in IUU fishing [19,55]. Similarly, we may question whether the same vessels and companies could be at heightened risk of being involved in other aspects of corporate misconduct or non-sustainable practices for which maintaining an elusive identity and/or deliberate corporate structure is key (e.g., capturing subsidies, avoiding taxes, laundering money, ensuring cheap and unregulated labor, etc.).

4.3. Limitations of the research

The scope was defined as tuna fishing vessels ≥ 20 m authorized to fish in the IATTC Convention Area in 2022. Data availability (presence of an IMO number, ownership information in Orbis) restricted the sample to 1648 vessels, corresponding to 92 % of registered vessels ≥ 20 m. However, the sample covers only 37 % of total tuna vessels in the IATTC's RVR. There were significant data gaps, particularly for countries in the Global South (Nicaragua, Costa Rica, Chile), but also for Canada (Table 2). Despite Chile representing the second largest flag state in the RVR, due to the restriction on vessel size, our sample included only a single vessel. Additionally, our study did not account for vessels engaged in illegal fishing within the IATTC Convention Area, with 13 such vessels identified by the IATTC in 2023 [107]. Due to these data gaps, we stress that the findings of this study should not be generalized to the entire tuna fishing fleet operating in the IATTC Convention Area, let alone the EPO.

This work was contingent upon the quality and comprehensiveness of secondary data sources. Orbis is considered "the most comprehensive commercially available company-level global database" [108], and is widely used by researchers for ownership analysis (e.g., [108–112]) including in the seafood industry [16]. In Orbis, ownership relationships are collected through the Ministry of Commerce in jurisdictions where ownership disclosure is mandatory, or otherwise from associated data providers, or directly from the companies themselves [80]. However, not necessarily all ownership links are included, and coverage depends on several factors, including company size, status, and ownership percentage. Yet, assessing the magnitude of missing data is difficult [108]. Data gaps persist notably for small companies [113], companies in lower income jurisdictions [112] or where beneficial and legal ownership registration laws are absent or incomplete [114], and companies registered in offshore financial centers characterized by secrecy laws, lenient regulation and low taxation [110].

Although BvD asserts that data are regularly updated and undergo rigorous quality control, neither the original data source nor details about the quality assurance procedures are available to the end user. Update frequency furthermore differs across countries, and company types. Marine vessel data are provided by IHS Markit and are updated monthly, while ownership data are updated weekly [80]. Fast-changing ownership of fishing vessels due to mergers and acquisitions is a major challenge [17], and despite regular updates, BvD appears to take longer to remove outdated companies and ownership links from the database. This may explain some minor anomalies in our results, such as two Japanese vessels owned by Russian GUOs, 25 Chinese vessels owned by Taiwanese GUOs, and a Chinese vessel owned by a Dutch GUO. BvD implemented a large-scale data update on 23 August 2023, encompassing most vessels included in our study. Following the update, the two Russian-owned Japanese vessels were listed as reflagged to Russia, suggesting that the observed country shift from the flag to the GUO level was only temporary, likely due to a vessel acquisition process or another corporate maneuver. However, this could not be confirmed. Second, the Dutch GUO presumably owning the Chinese vessel could no longer be found in Orbis, and the vessel was found to be owned by a Chinese company. Third, the corporate ownership of Chinese vessels by Taiwanese GUOs could not be confirmed based on 2024 data, as ownership

information was not disclosed for most vessels. More importantly, this effort revealed the presence of outdated vessel names, flags, and ownership information for the five remaining vessels (Table S11). We posit that while the recent update could provide an opportunity for a global analysis of vessel ownership in the coming years, errors like the one identified here could pose a significant flaw if they are widespread.

As a final remark, our reliance on a subscription-based commerical database like Orbis underscores the lack of reliable ownership data from public sources, such as government or RFMO databases. This limitation could be mitigated by governments or RFMOs mandating the collection and publication of corporate and beneficial ownership information of fishing vessels, or by enforcing the UNCLOS Article 91 requirement for a genuine link between vessels and their flag state [115].

Global Fishing Watch has become an indispensable source of information for researchers studying the distribution of DWF [14,20,55,116,117]. Still, imperfections remain, emphasizing the need for careful interpretation of the findings from this study. First, the algorithms detecting gear type and fishing activity may lead to the misclassification of some vessels and activities [118]. However, LL fishing (75 % of sampled vessels in our study) was found to have a comparatively high degree of accuracy [119]. Second, the MMSI number is, unlike the IMO number, not a fixed property of the vessel. It is a temporarily assigned identifier issued by the vessel's current flag state. Frequent flag changes may distort the relationship between MMSI and IMO reported in RFMO databases or by data providers such as Orbis. A study by Global Fishing Watch [120] found that the same MMSI is sometimes used by multiple vessels, which is likely due to a mistake in issuing the number by the competent authority but could also point towards the broadcasting of unauthorized MMSIs. The study furthermore identified instances of vessels intentionally using multiple MMSIs, underscoring a significant obstacle in effectively monitoring, controlling, and surveilling vessels based on remotely observed data. Requiring all fishing and support vessels to obtain unique identification numbers that are provided to the FAO Global Record, RFMOs and other relevant bodies may help mitigate this [120]. Third, there are gaps in the AIS record due to technical issues (e.g., poor satellite coverage, signal interference in crowded areas) and so-called 'disabling events', i.e., instances where operators turn off the AIS transponder to obscure the vessel's position (to enable unauthorized fishing or transshipment, to protect fishing grounds from competitors, or to avoid being detected by pirates) [116]. Blind spots are prediminantly found in coastal zones where satellite reception is poor [119]. This limitation could be mitigated by incorporating Vessel Monitoring System (VMS) data alongside AIS data, which would also increase the proportion of smaller inshore vessels that can be tracked [121]. However, to date, only 10 countries have made their VMS data publicly accessible through GFW [122]. Paolo *et al.* [106] estimate that 72–76 % of the world's industrial fishing vessels cannot be publicly tracked by AIS. For North and South America, AIS coverage is estimated at 17 % and 23 %, respectively. In our study area in 2020, we successfully tracked the fishing activity of 33 % of authorized (semi-)industrial tuna vessels in the EEZs and high seas surrounding the IATTC Convention Area. In future research, incorporating synthetic-aperture radar (SAR) data [106] could substantially increase the proportion of vessels that can be tracked.

The year 2020 was selected to align as closely as possible with the snapshot of ownership data extracted from Orbis (2022). However, it is well-documented that global fishing effort significantly declined during the COVID-19 pandemic, e.g., [106,123,124], which calls for caution when interpreting the results of our study. Yet, while our study may underestimate fishing nations' fishing hours under normal conditions, our findings regarding the distribution of fishing effort are consistent with those from other studies. The fishing activity hotspots we identified in the high seas of FAO areas 77 and 87 align with findings from studies analyzing GFW fishing effort data across various fisheries and broader temporal and geographical scales [14,73]. The relatively little fishing activity by industrial fishing vessels within EEZs is consistent with what is known about tuna fisheries in the WCPO and EPO. The majority of global high seas fishing effort identified by [14] was observed in the Pacific Ocean, which the authors attribute to tuna fisheries. We identified the Galapagos Islands EEZ as important for tuna fishing, which is consistent with recent findings [105].

Our methodology could not capture vertical relationships beyond ownership, such as leasing or contracting arrangements, nor did it account for beneficial ownership or the use of third-party management agencies for operating the vessels. Beneficial ownership analysis remains challenging due to important data gaps [125]. Yet, future research must include these aspects to fully understand the scope of ownership interests and corporate strategies of foreign companies, particularly in fisheries across the Global South. A particularly valuable line of research would be to apply beneficial ownership analysis to trace and quantify the financial [126] and nutrient flows [127]from the Global South to the Global North. Another point of attention is that applying the 50.01 % ownership threshold from the vessel to its ultimate owner may overlook the presence of smaller yet significant shareholders. Orbis offers the option to lower the threshold to 25.01 %. Beyond this, detailed shareholder analyses can be conducted for specific case studies to capture more nuanced ownership structures, which is especially relevant for identifying shareholdings in joint ventures.

5. Conclusion

These results indicate that ownership analysis of productive fishing capital is an essential element of responsible fisheries governance and management, especially for ensuring transparency, equitability and accountability. While increased accountability through ownership disclosure is important, there are other framings that remain underexposed, such as concentration of power, access to resources, and the flow of benefits from the Global South towards the Global North. Therefore, we urge managers and policy/decision makers to systematically collect ownership information, and to make this information publicly available. We recommend that efforts go beyond the disclosure of the corporate owners to include the beneficial owners of fishing capital, despite the known challenges surrounding the collection of such information. Furthermore, public ownership data must cover vessels' flag and ownership histories, such that hidden linkages and ambiguous vessel/owner identities can be revealed.

Ownership data may be used by fisheries managers for various purposes. First, knowing the corporate and beneficial owners of fishing vessels, licenses and fishing rights is key for holding perpetrators accountable in the case of fishing violations, infractions on labor law, tax evasion and money laundering [21,128]. Second, it contributes to a better monitoring of competition and concentration at sea and in the marketplace. It is well documented that high levels of concentration distort competition in the fishing industry [129–132]. Through the analysis of ownership structure, fisheries managers can detect early warning signs of a consolidating industry, such as shareholder dominance and centrality, and vertical integration. Third, there are serious equity concerns in certain fisheries, especially those where many DWF companies are active and where local coastal communities have restricted access to resources (e.g., competition between DWF companies and local fishers for resources or space, outflow of wealth and nutrients, etc.) [31–33]. This notably includes many tuna fisheries. In this context, ownership registers help managers keep track of which proportion of fishing capacity is locally vs. foreign owned and operated. This can help uncover hidden flows of wealth, raw materials and nutrients while also illuminating power dynamics, particularly within RFMO negotiations. For example, a few powerful corporations' overrepresentation in terms of fishing capacity and landings within the industrial PS fleet may grant them a disproportionate amount of power during RFMO negotiations, which further enhances their competitive advantage relative to the owner-operator small-scale sector, leading to the "*survival of the richest, not the fittest*" [33]. It is vital we acknowledge

the critical governance challenge of power and representation that lies at the heart of many RFMO negotiations.

Notable knowledge gaps remain. Our study has only superficially reviewed corporate strategies for capturing resources in the IATTC Convention Area (e.g., through ownership of vessels and/or companies). Further research is needed on their origin (e.g., forward or backward integration) and the material conditions that sustain them [54]. In this regard, developing a deeper understanding of the ontogeny and growth of large fishing corporations is crucial to distinguish between strategic decisions related to fishing (e.g., access to fishing grounds, cheap labor, and low regulatory oversight) and broader corporate considerations (e.g., tax avoidance, return on investment, ownership secrecy, and the presence of markets and infrastructure). Future research could focus on better understanding ownership relations in a political economy context of past and current North-South relations. The multitude of ownership structures calls for a case study approach parallel to studies assessing ownership at a regional or global level.

It is furthermore critical to evaluate how ownership affects the sustainability and equity of fishing operations, as well as the broader fishery and markets, and how it impacts the wider economic and social relations in the coastal states where the fish is caught but often not sold or consumed. Key aspects include examining the primary beneficiaries and driving forces behind the net flow of nutrients and benefits from the Global South to the Global North. Finally, many of the challenges and concerns raised here stem from, or are at least worsened by, a lack of identification and accountability from those with power. Therefore, enhancing transparency in its broadest sense is considered a crucial step toward improving fisheries governance and fostering trust in decision-making processes, ultimately ensuring a more equitable distribution of access, benefits, and political power [49].

Author statement

The authors declare that there is no conflict of interest. The authors are not in the position to share the primary data due to confidentiality agreements. However, the Supplementary Materials provide detailed information to support further understanding of the study's findings. Additionally, R scripts developed for the analysis can be made available upon request, contingent on collaborative arrangements.

CRediT authorship contribution statement

Natali Lazzari: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Conceptualization. **Arne Kinds:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gillian B. Ainsworth:** Writing – review & editing, Writing – original draft. **Daniel J. Skerritt:** Writing – review & editing, Writing – original draft, Validation, Methodology, Conceptualization. **Ussif Rashid Sumaila:** Supervision, Resources, Project administration, Funding acquisition. **Maria Lourdes Palomares:** Writing – review & editing, Writing – original draft, Validation, Resources, Formal analysis, Conceptualization. **Sebastian Villasante:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition. **Patricia Majluf:** Conceptualization. **Katina Roumbedakis:** Writing – review & editing. **Adriana Rosa Carvalho:** Writing – review & editing, Conceptualization.

Acknowledgments

This paper was made possible thanks to funding from USAID in the context of an international study on the impacts of Distant Water Fishing fleets. We would like to extend our special thanks to JoyDeLee Marrow (IATTC) for granting us access to the RVR, and to Jorge Martín Silván (Bureau van Dijk) for his help with the extractions of ownership data from the Orbis database. SV thanks the financial support from the EQUALSEA project (Transformative Adaptation Towards Ocean Equity), under the European Horizon 2020 Program, ERC Consolidator (Grant Agreement #101002784) funded by the European Research Council, and from the Gain Oportunius Program of Xunta de Galicia, to cover the costs of the Orbis database. The authors thank the reviewers for their critical reflection on the manuscript draft, which has significantly improved the quality and rigor of our work.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106474.

Data availability

The authors do not have permission to share data.

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