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IUU safe havens or PSMA ports: A global assessment of port State performance and risk

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ABSTRACT

The 2009 Port State Measures Agreement (PSMA) was the first legally binding international instrument to empower port States to deny foreign vessels suspected of having engaged in illegal, unreported and unregulated (IUU) fishing from using their ports and to land catches. This paper builds upon previous work analyzing 2020 AIS data to rank fishing ports globally and assessing evolving port State risk and port States performance in PSMA implementation. Internal and external indicators were identified to highlight the port States at risk of becoming exposed to IUU fishing transactions. This paper includes an analysis of designated port use, a key requirement of PSMA implementation. The paper also establishes an ongoing methodological framework for port associated IUU risk assessment using the outputs as a benchmark against which follow-up trend analyses are planned, the next using 2023 data. Port rankings evolved because of continued AIS adoption, port State business diversification and Covid-19 related disruptions. 3% of commercial port calls globally are made by foreign vessels. Globally, internal port State risk has dropped, while external risk has increased, the former driven by parties to the PSMA, and the latter by PSMA non-parties. Higher-risk fleets are now diverting to PSMA non-parties. The findings underline the transformational nature of the Agreement. Overall port State risk correlates more strongly with quality of governance than with national income. The paper finds that the PSMA's designated port entry rule for foreign vessels is currently weakly applied in advanced economies whilst it is more strongly applied across the developing world.

1. Introduction

The United Nations Food and Agriculture Organization (FAO) Agreement on Port State Measures (PSMA) was adopted in 2009 and entered into force on 5th June 2016. It is the latest binding international fisheries instrument to enter into force and regulates the entry of foreign fishing vessels into ports.[1] Measures provided under the Agreement empower port States to, *inter alia*, deny foreign vessels suspected of having engaged in illegal, unreported and unregulated (IUU) fishing from using their ports and to land catches [15]. Parties to the PSMA should make provision of equal bite regarding oversight of their domestic fleets in their capacity as flag States.[2] IUU fishing remains one of the most important and hitherto elusive challenges to overcome in the pursuit of achieving sustainable fisheries [1,2,5,24]. The existence of ports of convenience providing an avenue to IUU fishing vessels to land their catches, and some of their characteristics, have become the object

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1 See: PSMA PART 1 "GENERAL PROVISIONS", Article 3 "Application", paragraph 1.
2 See: PSMA PART 5 "ROLE OF FLAG STATES", Article 20 "Role of Flag States", paragraph 6.

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of studies more recently [19,25,31].

The steadily increasing requirement for fishing vessels of given sizes to transmit on the automatic vessel identification system (AIS)[3] is producing an ever-improving, open-source repository of fishing vessel movement data, generating opportunities to study fishing vessel activity from a multiplying range of perspectives [26,34]. The AIS datasets – of unmatched spatial and temporal resolution and transparency – can be used, *inter alia*, to also analyze the use that individual fishing vessels and fleets make of domestic and foreign ports worldwide, to identify and rank major ports catering to given types of foreign fleets (*e.g.* catchers and reefers[4]), and to carry out a deeper analysis of IUU risks correlating with these fleets and the port visits they effect.

A first AIS-based study analyzing fishing vessel movements into fishing ports globally was published in 2019, based on the 2017 AIS dataset broadcasted by the global fishing fleet. Hence, the snapshot provided in this paper follows the earlier one by three years. The first study resulted in a first ranking of fishing ports of global importance, and an analysis of risk factors related to the visits of given fishing vessels and fleets into foreign ports [19].[5]

The immediate objectives of the paper are threefold: It sets out to provide a current ranking of major world fishing ports, with the rankings based on the differing characteristics and metrics of fishing vessels visiting ports. This part of the paper is wholly rooted in the analysis of AIS signals broadcasted by the global fishing fleet. Secondly, it aims to provide a global analysis of port State exposure to IUU fishing risk within its fishing ports. This assessment gives rise to three scores per port State; internal risk (relating to presence or absence of broader measures setting out to counter IUU-fishing), external risk (relating to the profiles of vessels visiting ports) – and overall port State IUU risk, the latter being the arithmetic average of these two components. These results give rise to a notional risk score of port States across these three risk categories. Thirdly, an analysis of port State performance in combatting IUU fishing is undertaken, where the resulting port State IUU risk scores, *inter alia*, are contrasted against a number of other datasets (*e.g.* national income), to detect underlying drivers that condition port State performance, and to determine how such drivers may differ between world regions. This analysis also covers entries of foreign vessels into the ports of PSMA parties, to examine the degree to which designated ports now condition the movements of foreign fishing vessels.

This paper sets out to update the findings of 2019, referred above (forthwith referred to as the "*2019 study*"), and to expand on them where significant developments have occurred. The paper also aims, as appropriate, to contrast the current state-of-play with the situation documented earlier.

This paper is grounded in the 2020 AIS global fishing vessel movement dataset. This makes it prone to reflect all disruptions that the world fishing fleets came to know during the first year of the Covid-19 pandemic. The pandemic is known to have led to traffic reductions in some ports (and port States), and increases in others, as global fishing vessel movements have been affected by port entry suspensions. One such suspension was undertaken by the authorities of the Republic of the Marshall Islands in early April 2020, where the port of Majuro caters to in-port transshipments of WCPO tuna fleets. This traffic was largely deflected to other ports around the region[6] – the port of Rabaul (PNG) having been one of the principal recipients.[7] The implication is that the resulting global port movement statistics cannot be regarded as fully reflecting those of a "business-as-usual" year.

2. Methods

2.1. Port identification

Global Fishing Watch has created a global dataset of anchorages. The dataset was created by gridding the globe into roughly equal sized grid cells (called s2 cells) approximately 0.5 km on a side. Using a global dataset of AIS vessel positions from Orbcomm and Spire, all grid cells in which at least 20 vessels remained stationary (a maximum distance travelled of 0.5 km) for at least 12 h were identified. The mean location of all stationary events within a grid cell was recorded as an anchorage point and resulted a global dataset of 166,514 anchorage points.

For this paper, each anchorage point was identified using a tiered labelling procedure. Anchorage points were initially labelled using a list of known ports provided by government partners (*e.g.* Indonesia KKP,[8] Directorate of Hydrography and Navigation of the Peruvian Navy). Any remaining unlabelled anchorage points within 5 km of a World Port Index (WPI) port[9] were assigned the WPI port name. Any remaining unnamed anchorage points within 5 km of a location listed in the Geonames 1000 database[10] were assigned the corresponding city label. Any anchorages remaining unlabelled were assigned a label based on the most common value in the "destination" field in the AIS message for all vessels that were used in the initial creation of the anchorage point. Anchorage names are reviewed and manually updated where necessary using global maps and local or regional knowledge. Port States are reported in standard ISO3 format and are assigned using a land and marine boundary union.[11] Overseas Territories with their own ISO3 are not labelled separately from the associated sovereign nation in this dataset. For example, the port of Las Palmas de Gran Canaria is listed under Spain (ESP), and the port of Tórshavn in the Faroe Islands (FRO) is listed under Denmark (DEN).

Anchorage points were aggregated into ports using a combination of automated and manual methods. An initial clustering was performed by identifying which anchorage points were most commonly visited in sequence, creating a network of anchorage linkages and identifying strong linkages between some anchorage points and weaker connections between others. A Louvain's community detection algorithm was applied to the anchorage visit network, identifying clusters of more densely connected anchorage points. In some regions these clusters represent entire ports, while in others they represent subregions within a larger port or delineated offshore or harbour anchorages from quayside berths. These clusters were manually reviewed and, in some cases, adjusted to include or exclude specific anchorage points based on review

[3] See for instance Article 10 "Automatic identification system" of the European Union's Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy.

[4] "Reefers" are defined as fish carrier vessels that receive fish from catcher vessels during in-port or at-sea transshipments and will be landing the fish *in lieu* of the catcher vessels from which they have received such catches. Reefers are regarded as full-fledged fishing vessels in the overwhelming majority of regulatory frameworks, and the PSMA applies to them in the same manner as it does to catcher vessels.

[5] The 2019 study had been preceded by a similar study in 2015, setting out to rank the world's most important commercial fishing ports based on declared volumes of fish landings. [20]

[6] Republic of Marshall Islands 2019 novel coronavirus (COVID-19) updated interim health travel advisory & restrictions. ISSUANCE 11: As of 2 April 2020; "[…] *Fishing vessels that transited through or departed from COVID-19 infected countries are temporarily suspended from entering the RMI ports until further notice. All fishing vessels exempted by MOHHS, RMI Ports Authority, MIMRA and RMI Immigration are strictly required to spend 14 days at sea prior to entry and must adhere to the National Disaster Committee approved Standard Operating Procedures-Maritime (SOP). Human-to-human contact is strictly prohibited.* […]"

[7] "The port of Majuro lost an estimated 60–70% of fishing vessel traffic and transshipped volumes in 2020 (over previous years), owing to the Covid-19 pandemic and the restrictions applied to foreign fishing vessel movements." (Pers. communication: Francisco Blaha; Adviser to MIMRA)

[8] http://pipp.djpt.kkp.go.id/profil_pelabuhan/kategori_pelabuhan

[9] https://msi.nga.mil/Publications/WPI v2019

[10] http://www.geonames.org/export/

[11] https://www.marineregions.org/ v3 2020–03–17

of the original anchorage naming, regional maps and port descriptions, or alternate data sources (UN LOCODE,[12] MarineTraffic[13]). Clusters that represent subregions or sub-ports within a larger port are manually aggregated and assigned to a common port using the same datasets for review.

2.2. Port visits

Port visits in 2020 were identified using the same global dataset of AIS vessel positions from Orbcomm and Spire as used to develop the ports database. Port visits were initially identified at the level of an anchorage point using the following logic. A vessel 'enters' an anchorage when an AIS position is within 3 km of an anchorage point and 'exits' with a position more than 4 km away from an anchorage point. Anchorage entry and exit distances were different to prevent vessels at the boundary from repeatedly entering and exiting the anchorage. To avoid recording port entries as a vessel transited near an anchorage (meeting the basic entry and exit criteria), two additional events were defined, anchorage stops and anchorage gaps. An anchorage stop begins when a vessel is within 3 km of an anchorage point, with a speed less than 0.2 knots, and ends when the vessel speed is greater than 0.5 knots. An anchorage gap begins when a vessel is within 3 km of an anchorage point and has a gap of longer than 4 h between AIS positions and the event ends at the next AIS position that is received. Gaps in AIS are not unusual for vessels in port as many vessels turn off their AIS while in port. In this paper, we included anchorage visits that include at least one port stop or port gap event, to ensure that in addition to 'entering' an anchorage, a second event had to have occurred. Visit counts to anchorage points were aggregated to anchorage clusters and ultimately to ports.

To avoid inflating port visit counts with vessels that briefly exit and re-enter port, each voyage prior to a counted port visit had to meet a set of criteria depending on the duration, as well as the start and ending locations of the voyage.

For this paper we included port visits:

1. following voyages that were longer than one hour and involved a vessel travelling between different ports.
2. following voyages of any duration that involved a vessel exiting and subsequently re-entering the same port, as long as during the voyage the vessel had an encounter event with another vessel, a loitering event of at least 2 h, or a fishing event.
3. following voyages of any duration that involved a vessel exiting and subsequently re-entering the same port as long as the voyage duration was greater than 24 h.

Port visits during which no port event (port stop/port gap) had a duration longer than three hours were removed from consideration as manual review identified such port visits as error prone, often representing river transits. All port visits were counted regardless of the reason for a vessel to enter a given port.

In the port entry logic outlined above, an *encounter event* was defined as two vessels being within 500 m of one another for at least two hours, travelling at speeds of less than two knots, at least 10 km from an anchorage point. A *loitering event* was defined as a single vessel travelling at less than two knots for at least two hours while at least 20 km from an anchorage point [27].

A *fishing event* was defined using the GFW fishing algorithm, which determines if an AIS position represents a fishing location [21]. A fishing event aggregates fishing locations using a set of rules:

1. A fishing event may be represented by at least five fishing positions as long as any two consecutive fishing positions are not separated by more than two hours or 10 km, the average speed of the entire event is less than 10 knots, and any two fishing positions separated by any intervening non-fishing positions are not more than one hour or two kilometres apart.
2. A fishing event may have fewer than five positions as long as the total time range of the event is greater than 20 min, any two consecutive fishing positions are not separated by more than two hours or 10 km, the average speed of the entire event is less than 10 knots, and any two fishing positions separated by any intervening non-fishing positions are not more than one hour or two kilometres apart.
3. A fishing event may have fewer than five positions or a duration of less than 20 min as long as the total event covers more than 0.5 kilometres (50 m for squid vessels), and any two consecutive fishing positions are not separated by more than two hours or 10 km, the average speed of the entire event is less than 10 knots, and any two fishing positions separated by any intervening non-fishing positions are not more than one hour or two kilometres apart.

2.3. Fishing vessel identity (MMSI) & characteristics

Vessel identity information for each catcher and reefer vessel was drawn from Global Fishing Watch's vessel database which matches identities from > 40 vessel registries to AIS data to reveal identity history for ~32,000 fishing and support vessels. The registry sources include 13 RFMO registries (CCAMLR, CCSBT, GFCM, IATTC, ICCAT, IOTC, NAFO, NEAFC, NPFC, SEAFO, SIOFA, SPRFMO, WCPFC), national authorities and regional bodies (Australia, Canada, Chile, Chinese Taipei, Costa Rica, European Union, Pacific Islands Forum Fisheries Agency, Faroe Islands, Iceland, Republic of Korea, Malaysia, Norway, Panama, Peru, Russia, Seychelles, United States of America), the FAO Global Record, and the global integrated shipping information system (IMO GISIS), among others. Registry sources were matched to AIS using a scoring system that assigns matches based on the number of aggregated identity fields that match between the two datasets and then combined to produce the most representative identities for a particular period.

The list of fishing vessels used in this paper was created by combining these registry sources with GFWs vessel classification machine learning algorithms to produce a complete list of global fishing vessels detected using AIS [21,34]. GFW also maintains a complete list of refrigerated carrier vessels matched to AIS produced through a combination of official vessel registries; GFW's vessel classification algorithms, which identify vessels based on their behaviour; and a manual review of vessels that had encounters with other vessels at sea [27].

The vessel flag State identity was drawn from registry information, but when unavailable assigned based on the first three digits of the MMSI (MID code). Vessel flag State was reported using the standard ISO3 format, with overseas territories generally combined with their counterparts flagged to the sovereign nation. For example, vessels flagged to Reunion (REU) were considered alongside vessels flagged to France (FRA). We used Chinese Taipei when referencing Taiwan as a location or a coastal/port/market state, Chinese Taipei EEZ when referencing the exclusive economic zone and the "Fishing entity of Taiwan" when referencing the flag State. The standard ISO3 code of TWN was used. Hold size while reported by a few registries was not widely available in consistent units and for this reason, we estimated hold size for all vessels following the methods and relationships developed in the 2019 study (see Appendix E).

2.4. Port State risk analysis and ranking

Risk analysis is based on the computation of an internal risk score, an external risk score, and the combination of both, yielding an overall port State IUU risk score for every port State covered by the paper.

[12] https://unece.org/trade/cefact/UNLOCODE-Download
[13] www.marinetraffic.com

The internal risk score provides a measure of the performance of the State in mitigating IUU risk relating to foreign fishing vessels entering its ports. None of the internal indicators score direct real-world performance in mitigating the entry of or monitoring of transactions of higher risk vessels in port.[14]

The external risk score provides a measure of exposure of the port State to potential IUU fishing operations and related transactions in port. The former relies primarily on published open-source data and information, such as the ratification of major international agreements or State performance in complying with RFMO mandates, while the latter is grounded in the characteristics of foreign vessels visiting ports, with their movements into ports invariably being informed by AIS data. Characterizing port State risk *via* the profile of visiting vessels has been applied in other studies also (*e.g.* [33]).

The straight arithmetic average of the scores of both risk categories yields the overall port State risk score. Internal and external risk are derived from several component indicators. Individual indicators embody risk factors that either mitigate or aggravate risk of exposure to IUU and/or facilitation of IUU fishing. Eight indicators make up the internal risk component, and seven indicators make up the external risk component (see Table 1). Indicators are individually weighted (low, medium or high), determining their relative weight within each of the risk components. A high weighting was assigned to indicators where a direct link to IUU fishing risk is generally recognized. An intermediate weighting was given to indicators where a more indirect, but strong and generally recognized correlation with IUU fishing exists. A low weighting was assigned to indicators where a direct link and/or a strong correlation is not given, but where risks of IUU fishing transactions would be expected to arise as a concomitant phenomenon.

Table 1
Component indicators forming the Port State IUU Risk Score.

Risk component	AIS-based	Weighting	Indicator name
General	yes	n/a[a]	1. Operates commercial ports in which fishing vessels do business
Internal	yes	3	2. Number of commercial fishing ports
	no	2	3. Party to the 2009 Agreement on Port State Measures
	no	2	4. Contracting Party (CP) or Cooperating Non-Contracting Party (CNCP) of an RFMO with a binding PSM resolution & transparent compliance monitoring
	no	3	5. Compliance record with binding RFMO port State conservation and management measures (CMMs)
	no	2	6. Transparency International Corruption Perceptions index of the port State
	no	1	7. Identification status of the port State - by the EU
	no	1	8. Identification status of the port State - by the USA
	no	2	9. Identification status of the port State - within any RFMO
External	yes	2	10. Port visits by foreign fishing vessels
	yes	3	11. Flag of Convenience (FOC) State fishing vessels entering ports (plus unknown MMSI)
	yes	3	12. Average flag State Corruption Perceptions index of fishing vessels entering foreign ports
	yes	3	13. IUU listed fishing vessels entering ports
	yes	2	14. EU carded flag State fishing vessels entering ports
	yes	2	15. US carded flag State fishing vessels entering ports
	yes	2	16. Average internal port State risk of fishing vessels entering ports[b]

[a] This indicator is not weighted. It is used to merely decide whether a country is included in the overall data set of countries assessed, or conversely, whether it is to be excluded.

[b] As calculated from indicators 1–9 in the same table for the same year of reference.

All scores are qualitative in nature, and do not have a quantitative function other than enabling comparison of risk and performance between countries and regions. Scores cannot be used to quantify volumes, values or types of IUU vessel entries and landings. Owing to the absence of indicators directly scoring the actual implementation of mitigation measures (*e.g.* the degree of foreign vessels entries into designated ports – see discussion also), and the absence of confidence intervals for country scores, individual country scores and ranks must be seen as indicative only, coming with some degree of uncertainty. Real-life exposure and performance of individual port States can only be established through studies measuring these factors directly through meaningful field-based research protocols.

Component indicator scores are segmented into five tiers, ranging from 1 to 5 as full integers. 1 stands for “yes” and “very good”, while 5 stands for “no” and “very poor”. Care was taken to ensure indicators are symmetrically arranged, when not all five tiers are used (*e.g.* in yes/no type indicators). All indicators use 2, 3 or 5 tiers to assign scores. Overall, this implies that low Index scores provide for “low IUU risk”, and that high scores stand for “high IUU risk”. Table 1 also shows which indicators are based on AIS data. Overall, 9 out of 16 indicators are AIS-based, while seven are drawn from other fact-based sources.

One hundred and fifty-three independent coastal States were first selected as the object of this paper. Only States in which AIS-fitted fishing vessels were detected to have entered at least one port were retained for scoring. This led to the elimination of 13 coastal States from the initial group of 153 States, leaving 140 port States as the object of the more detailed analysis.[15] Some of the coastal States that were eliminated, *e.g.* Belize and Timor Leste, are port States, providing a continuing indication of the limitations of working with AIS-determined data only.

Data for all indicators are sourced from recently available datasets – mostly 2020 – with possible minor variations between indicators. This provides for temporal proximity between the AIS dataset and the indicators serving to define internal and external risk. A detailed description of individual indicators is provided in Appendix A, including notes on individual indicator methodology.

2.5. Port State performance analysis

In the port State performance analysis, the internal, external, and/or overall risk scores are compared to a range of factors, including indices external to this paper (such as national income or quality of governance), to examine how such factors correlate with port State IUU risk, assisting in identifying stronger and weaker performers in the domain of PSMA implementation.

Foreign vessel characteristics are the exclusive component of external port State risk. While internal risk can be established for all countries, external port State risk can only be determined for States into whose port(s) foreign vessels have entered over the study period (*i.e.* the full calendar year 2020). Among the 140 coastal States which were

[14] This may give rise to perceived dissonances between the performance scores and rankings of individual port States in this paper, and the real-life performance of the same as perceived by individual experts familiar with the actual situation.

[15] In the 2019 study, these numbers were the same, but the States dropping out of the analysis were not all the same. This implies that some that were not included in the wider analysis in 2019 – *e.g.* Barbados – are now included here, while a few others that were included in 2019, are not included here.

identified to operate fishing ports based on AIS data, two port States were identified as not having had any visits by foreign vessels; *i.e.* Bahrain and Nicaragua. In those performance assessments where the external risk component plays a structural part (*e.g.* internal *vs* external risk score correlation analysis), these two countries are eliminated from the analysis. For Bahrain and Nicaragua, their internal and overall IUU risk score is the same.

These performance analyses are generally graphed out, and statistical analysis is performed in all cases. To compare the means between two samples (*e.g.* the risk scores of port States having signed the PSMA *versus* those that have not), a one-tailed two-sample t-test with equal variance was used, having established in all cases that variance in both samples is comparable. To test the significance of a correlation (*i.e.* a causal effect relationship) between two variables (*e.g.* correlation of external port risk with internal port risk), a simple linear regression analysis using the least squares method to fit a line through the set of observations was performed, having established in all cases that residuals were randomly distributed around the average, and verifying in all cases that the relationship was linear indeed – validating the appropriateness of simple linear regression analysis.

The significance level used in these tests, for the observed difference between sample means and/or the observed slope, is < 0.05.

2.6. Data sources and robustness

Port State risk analysis was informed by indicators for which the majority of data was obtained from information sources existing outside of this study. The indicator sources used in the paper fall into two categories, as follows (see details in Appendix A):

1. AIS data;
2. Published public-domain data sources hosted by international bodies.

Key characteristics of these datasets are as follows:

2.6.1. AIS data: caveats in determining vessel movements and identity

Limitations to the methods adopted in this paper are common to many AIS-based analyses, in that (i) fishing vessels are exempted from AIS requirements (unless required by their flag State); (ii) AIS is typically only fitted to large vessels (>300 GT) on international voyages; (iii) the quality of AIS data will depend on the type of unit used onboard and on satellite or terrestrial sensor coverage; and (iv) AIS can be switched off, and therefore such analyses may miss some vessels, events or patterns of behavior. However, its prevalence on large fishing vessels makes it useful for this study, which covers industrial-scale fishing vessels involved in longer-distance fishing operations susceptible to calling into foreign ports, triggering requirements under the PSMA.

Automated analysis of AIS data using machine learning poses additional limitations to the above, and the analysis of port use by foreign vessels is no exception – *i.e.*, certain non-relevant vessel behavior might be mistaken for port calls and vice-versa. In preparation of the work behind this paper, specialists from Trygg Mat Tracking (TMT) conducted quality assurance in terms of AIS data characterization and definition as well as subsequent data compilation and analysis, to minimize such occurrences.

The utility of AIS data for detecting port visits is thus dependent upon the proportion of vessels operating with AIS and the ability to detect sufficient nearshore AIS messages to identify port visits. The proportion of vessels using AIS varies by vessel size and geography. Most vessels over 24 m operate with AIS and the fraction declines with decreasing size [34]. Flag States also vary in their AIS requirements such that vessels from some flag States may be more visible than others [34]. Such differences in AIS use must be considered when interpreting AIS derived port visits. Additionally, in areas of high vessel density with limited AIS reception by terrestrial receivers, satellite receivers may not detect all AIS messages and some vessels may not be tracked well [34]. While satellite reception may be a challenge close to shore, but outside of terrestrial receiver range, this is less likely to affect port visits as these typically occur close to shore and routinely within range of a terrestrial AIS receiver.

The database used to determine vessel identity was developed by combining data from over 40 registries available either in the public domain or from authorities and researchers, including registries from regional fisheries management organizations (RFMOs), national registries, and lists curated by researchers with identity information from within the AIS messages [30]. In some cases, vessels observed in AIS could not be matched to registries and thus their identity information, including flag State were derived solely from the AIS data. The limitations in using AIS data, related to vessel size, outlined above, and the fact that some vessels are not listed on public registries, result in better identity information for large vessels that operate under specific flag States or are listed on specific public registries. The identities of the remaining vessels are by necessity inferred from their AIS information and their activity.

2.6.2. Published public-domain data

Open-source public-domain data were used for the component indicators of internal and external risk. A specific weighting and scoring bands from 1 to 5 were assigned to each component indicator. The key to assigning scoring bands is documented in Appendix A for every individual indicator.

Publicly hosted data providing these indicators are generally published in a single place and generally cover all countries in this paper. The same applies to external indicator sets used in the correlation analyses. Such datasets, the period they cover, and their sources are summarized in Table 2.

Transparency International's Corruption Perceptions Index (CPI) lacks scores for some countries. In the analysis where the CPI is used, unscored countries are eliminated from the sample. This leads to a slightly smaller yet fully representative sample, does not affect the validity of the analysis, and is documented in the results section.

2020 datasets were used to coincide with vessel movement data. Where historic datasets were not available (*e.g.* the IUU vessel list at the beginning of 2020), the dataset available at the time of writing was used (2021/2022). In instances where a 2020 dataset had not yet been published, the 2019 dataset was used. The few instances of data misalignment between years have very limited or no impact on the global level analysis and the obtained results. The period applying to each dataset is also documented in the detailed indicator descriptions in Appendix A.

The overall solid quality of these data is determined by the methodologies applied by the organizations producing and hosting them. The discrepancy between style and content of RFMO compliance reports required a certain amount of discretion in deciding whether individual States ought to be considered as being in default with given RFMO PSM conservation and management measures (CMM) or not (indicator 5). In some cases, the EU is mentioned as being in default, rather than a specific EU member State. In such cases, all EU members with vessels active in that RFMO are negatively scored in their capacity as a port State – constituting a conservative approach ensuring countries do not appear with potentially better scores than they should have.

3. Results

The entire analysis and the results obtained is/are exclusively based on the port movements of fishing vessels broadcasting their positions on AIS.

3.1. Fishing port rankings

The figures and embedded tables below rank the top 15 global ports along various metrics, with each pair of figures ranking top ports by

Table 2
Indicator year and source.

Port State risk indicators (internal & external)		
Indicator #	Object and timestamp of dataset	Source
Indicator 1	Operates at least one fishing port (2020)	this study
Indicator 2	Number of commercial fishing ports (2020)	this study
Indicator 3	PSMA party (by January 2020)	FAO
Indicator 4	Contracting or Cooperating Non-Contracting Party of RFMO with a binding PSM resolution & transparent compliance monitoring (2020)	this study / RFMO CMMs
Indicator 5	Compliance record with binding RFMO port State CMMs (2020, or 2019 where 2020 report not yet available)	RFMO compliance reports
Indicator 6	Corruption Perceptions Index of the port State (2020)	Transparency International
Indicator 7	Identification status of the port State under the EU IUU Regulation 1010/2008 (by January of 2020)	EU / DG MARE
Indicator 8	Identification status of the port State under NOAA's biennial report to the US Congress (2019 report)	USA / NOAA / Congress
Indicator 9	Identification status of the port State within RFMOs (2020, or 2019 where 2020 Commission report not yet available)	RFMO Commission decisions
Indicator 10	Port visits by foreign fishing vessels (2020)	this study
Indicator 11	Flag of Convenience fishing vessels entering ports (2020 listing); plus unknown MMSIs	ITF Seafarers / this study
Indicator 12	Average flag State Corruption Perceptions Index of fishing vessels entering foreign ports (2020); same source as indicator #6 (above)	Transparency International
Indicator 13	IUU listed fishing vessels entering ports (2022)	Trygg Mat Tracking
Indicator 14	EU carded flag State fishing vessels entering ports (by January 2020)	EU DG MARE / this study
Indicator 15	US carded flag State fishing vessels entering ports (2019 report)	NOAA / this study
Indicator 16	Average internal port State risk of foreign fishing vessels entering ports (2020)	this study
Other indicators used in the port State performance analysis (correlations)		
National income	National income group (2020)	World Bank
GNI per capita	Per capita gross national income, PPP (current Int'l $) (2020)	World Bank

number of visits and hold volume. See Appendix C for top 100 rankings in table format.

When ports are ranked by total visits of all vessel types combined – domestic and foreign combined or domestic only (Figs. 1 and 3) – Chinese ports dominate, and the top 15 ports are all Asian. While the exact ranking differs between 2019 and the overall number of port visits is greater in the present paper, many of the same top ports emerge. When focusing on total foreign visits by all vessel types, there are some shifts with Nouadhibou, Mauritania, Castletown-Bearhaven, Ireland and Vila Real De Santo Antonio, Portugal ranked more highly in the present paper, while a number of ports such as Majuro, Republic of Marshall Islands, Suva, Fiji, Port Louis, Mauritius, Manta, Ecuador, Pohnpei, Federated States of Micronesia, and Abidjan, Cote d'Ivoire that were ranking higher in 2019 either moving lower or dropping from the list of top 15 ports altogether (Fig. 5).

Comparing ranked lists of ports by domestic catcher hold size between 2019 and present identifies a set of common ports (8 of 15 in common) while Vladivostok, Russia and Zhoushan, China switch positions at the top of the rankings (Fig. 4). The present paper identifies far fewer visits to Zhoushan, China, while adding new Chinese ports and Dutch Harbor, USA as well.

Switching to ranking ports by foreign catcher vessel hold size (Fig. 8) we again see ports like Majuro, Republic of Marshall Islands and Manta, Ecuador, ranked lower in the present paper and ports like Nouadhibou, Mauritania and Port Victoria, Seychelles moving higher, when compared to the 2019 study results. Majuro which was ranked 1st in the 2019 study represented less than two percent of foreign catcher hold size in the present paper and dropped to place 14 (Fig. 8). Using the same metric, Nouadhibou, Mauritania went from ranking 5th in the 2019 study to ranking 1st here, with a more than 3-fold increase in foreign catcher hold size.

Port rankings by foreign reefer hold size also differ considerably between datasets, though Busan remains ranked 1st. Several ports previously not listed entered this list in 2020, including ports in the Philippines, Europe, and Japan, replacing a number of ports in the Pacific and along the Atlantic coast of Africa (Fig. 10).

When appraising these rankings, and the shifts that are detected, it is important to bear in mind that the technology on which these rankings are based (*i.e.* AIS signals) continues the process of adoption and expansion, and that some of the shifts that are detected *(e.g.* Dutch Harbour, USA, joining the top 15 ports on domestic hold size volumes – Fig. 4) may relate to the fact that more signals are now received from within ports and jurisdictions where domestic adoption of the technology in the fishing sector may have picked up more recently.

3.2. Port State risk and performance analysis

3.2.1. Global port entry analysis: domestic and foreign entries by region

The global 2020 AIS dataset tallies a total of 1,705,358 fishing vessel port entries. Of these, 1,655,429 were made by vessels into domestic ports, and 49,929 were made by vessels into foreign ports. Hence, only 2.93% of detected port visits were made by foreign vessels and fall under the strictures of the PSMA.[16]

Vessels flagged in the Europe region made 56.8% of global 2020 vessel calls into foreign ports (of which the ports may be in the same, or in a different world region) (Fig. 11). Vessels flagged in Europe are followed by vessels flying an Asian flag (21.4%), followed by vessels flying a Latin American and Caribbean region flag (12.9%).[17] The four remaining world regions (Africa, Southwest Pacific, North America and the Near East – in descending order) provided a mere 8.9% of global vessel entries into foreign ports.

Regarding the types of ports (national or foreign) fleets of given regions call into, vessels flagged to States of the Latin American and Caribbean region stand out as those making most foreign port calls – in relative terms (25.6% of all calls) (Fig. 12). Though vessels flagged in Europe made more than half of all global foreign port calls in 2020 (Fig. 11), only 4.6% of all port visits by vessels flagged in Europe were into foreign ports. For vessels flagged in the USA and in Canada (North America region), $< 1\%$ of port entries occurred into foreign ports. Combined with the fact that only 1.2% of the global foreign port entries was made by vessels from this region (Fig. 11), and that few foreign fishing vessels call into North American ports (1.7%) (Fig. 13), this indicates that North American commercial fisheries are largely "domestic" and self-contained when it comes to global fishing vessel movement patterns and are operationally quite distinct from all other world regions from this perspective.

[16] Note that for this statistic, the entry of a vessel of an EU Member flag State into the port of another EU Member port State is computed as a foreign port entry. If the EU's way of classifying intra-EU vessel port movements as domestic was applied, then the global percentage of foreign port entries to which the PSMA framework applies would be further reduced still.

[17] If the EU's approach of considering non-domestic EU vessel port entries as domestic was applied, and noting the entry of 12,683 non-domestic EU entries into ports of other EU members in table 17, and assuming that Spain – the only important EU port not listed in table 17, owing to its late designation of ports in 2020 and 2021 – received a similar level of non-domestic EU vessel calls as Portugal did, Europe region vessel entries into foreign ports would drop by some 14,000 vessel entries. Under this premise, Europe would still retain its top position as the world region whose vessels visit foreign ports most.

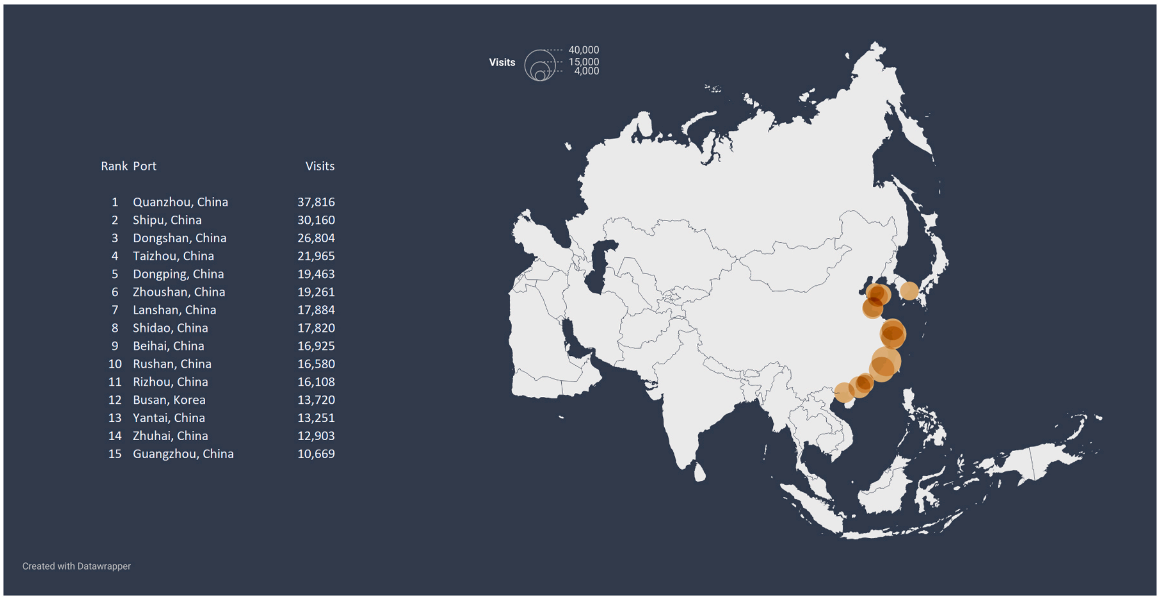

Fig. 1. Top 15 global ports for total catchers & reefers (domestic & foreign) by no. of visits.

Fig. 2. Top 15 global ports for total catchers & reefers (domestic & foreign) by hold size (m^3).

3.2.2. Global port entry analysis: foreign entries by region and by income group

49.9% of all foreign port entries occurred in the Europe region (Fig. 13), reflecting the Europe region's importance as the world's largest import market for seafood [14].[18] The lowest number of foreign vessel entries occurred in the Near East (1.5%) and North America (1.7%). Africa is the world region where most foreign vessel port calls were made into lower middle and low-income States, followed by the Southwest Pacific, where it was about 1 in 2 foreign vessels entering a port of a lower middle-income country. The Europe region, receiving close to 1:2 of total global foreign port entries, the vast majority of port entries take place into high income economies.

3.2.3. Global and regional port State risk score distribution and ranking

Global port State risk has dropped marginally, relative to the 2019 study results (Table 3). The overall global risk score is down 0.52%, sustained by a global drop of 1.83% in internal port State risk, and weighed down by a global rise of external risk of 0.96%. The rise of external risk globally, against a relative two-fold drop in internal risk may have been driven by uncertainties and vessel movement anomalies induced by the Covid-19 pandemic.

Table 4 reproduces the risk score values by category and by region. Green scores are those that have improved over earlier scores, and red scores denote those that have weakened. The only region scoring worse

[18] In line with the footnote relating to Fig. 11, if the EU's approach of considering non-domestic EU vessel port calls as domestic calls was applied, Europe's relative importance would drop sharply as a result. However, it would still retain its top position as the world region whose ports are visited most by foreign vessels – still marginally outranking Asia – and the relative portion of visits to lower and upper middle income country ports would more than double from 5.8% to about 13.4%.

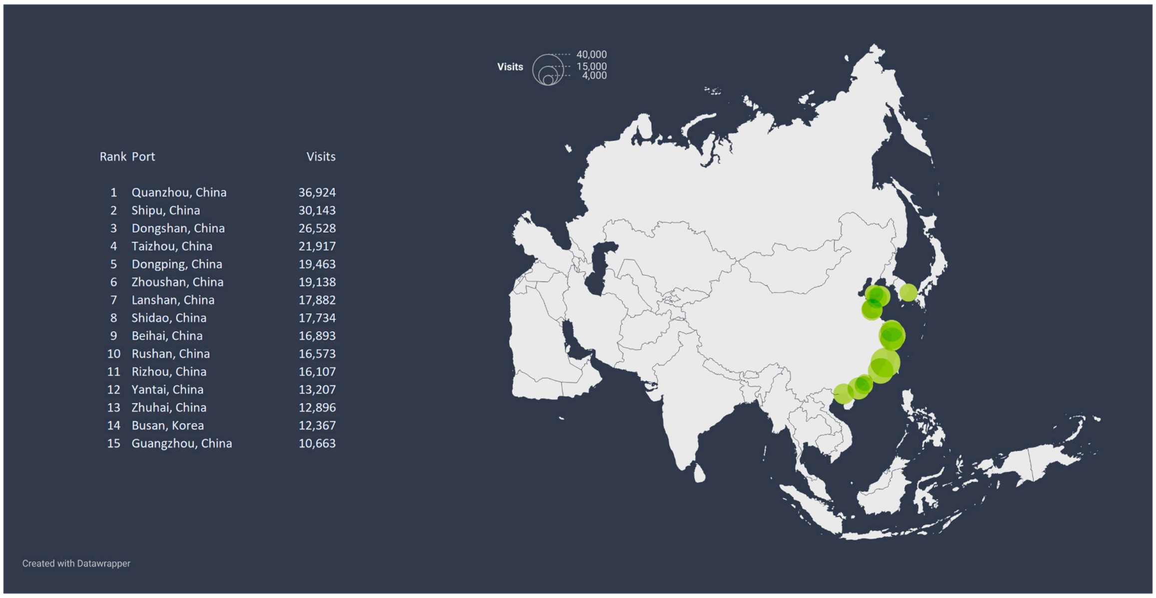

Fig. 3. Top 15 global ports for total domestic catchers & reefers by no. of visits.

Fig. 4. Top 15 global ports for total domestic catchers & reefers by hold size (m^3).

across the three risk categories is Latin America and the Caribbean. While the Near East and the Southwest Pacific score worse for external risk, only the Near East carries this outcome forward into overall risk also.

It arises from the distribution of gaining and losing regions between risk categories, that external risk is the category facing most challenges, with three regions obtaining a worsening risk score, and one staying put (Africa), against merely a single region weakening in the internal risk category. Latin America and the Caribbean and the Near East are the two world regions in which port States face the highest overall IUU risks, and they are also the only regions with a weakening overall risk score.

When comparing the average overall score by region to the 2019 study results,[19] Latin America & the Caribbean, slipping from 3rd to 6th rank, appears as the region that drops furthest in ranking, while most other regions slip up. Its drop is fueled largely (>64%) by the deterioration of its external risk score. The same is true for the Near East, retaining its bottom ranking position, and with its deteriorating overall risk score entirely fueled by external risk.

Fig. 14 renders the distribution of overall risk scores by region, with regions ordered by descending median overall risk score, revealing the spread of overall risk within and between regions. All coastal States with

[19] 2019: Near East > Asia > Southwest Pacific > Africa > Latin America & the Caribbean > Europe > North America2022: Near East > Latin America & the Caribbean > Asia > Southwest Pacific > Africa > North America > Europe

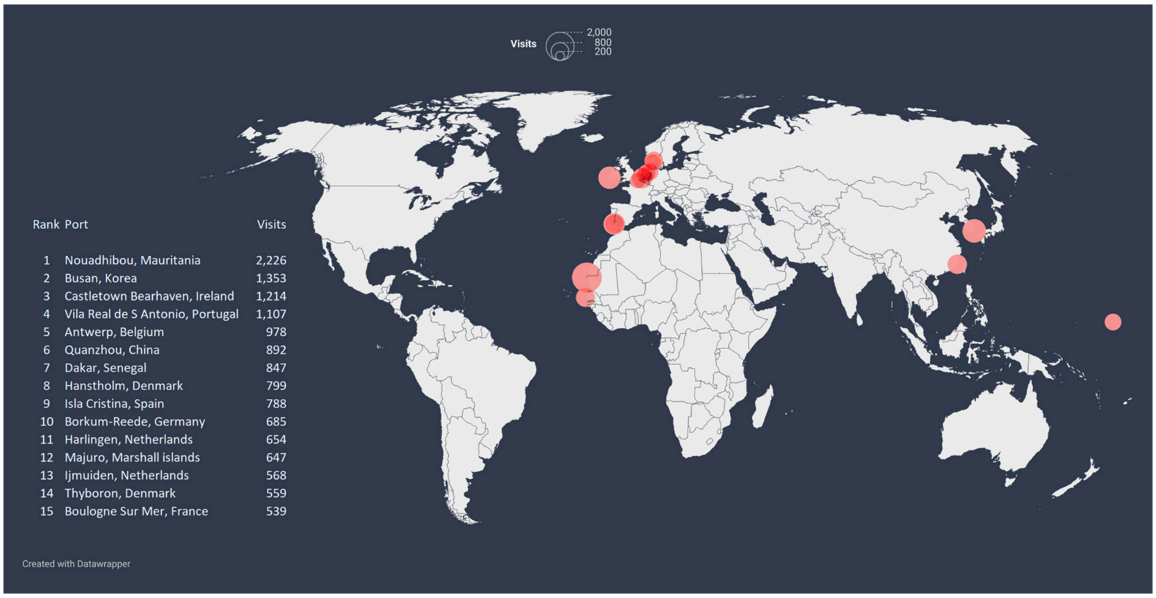

Fig. 5. Top 15 global ports for total foreign vessels (catchers & reefers) by no. of visits.

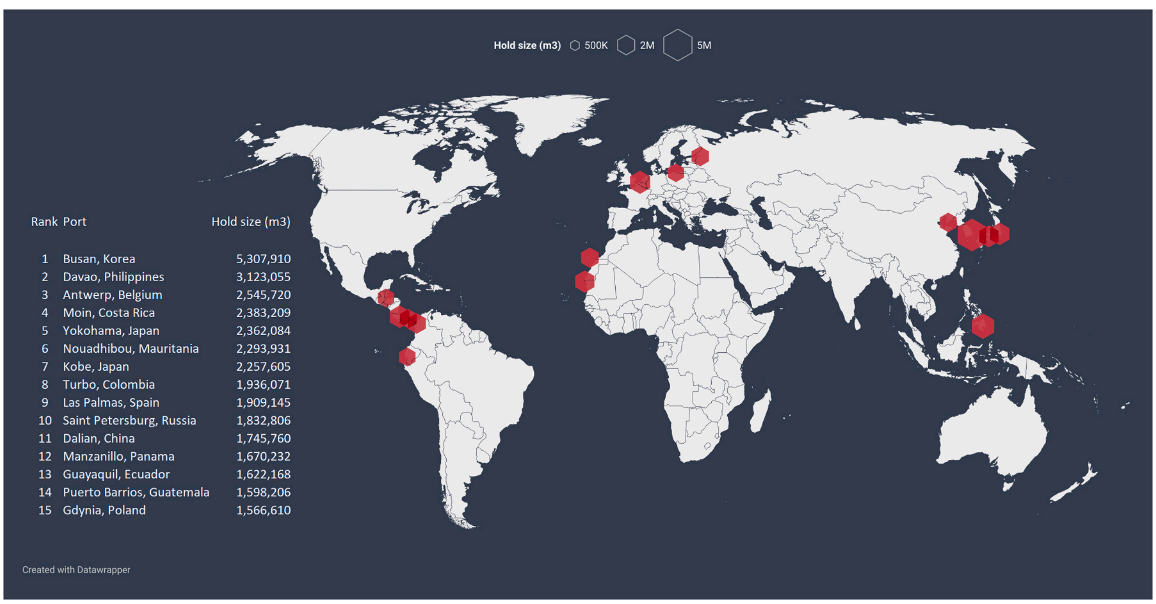

Fig. 6. Top 15 global ports for total foreign vessels (catchers & reefers) by hold size (m^3).

no AIS-vessel entries were excluded from the analysis (n = 140). The inter-quartile range[20] is more important for the Near East, Latin America & the Caribbean, the Southwest Pacific and to a lesser degree Africa, while both Asia and Europe scores result in palpably less dispersion at this level. In the Southwest Pacific, there is a substantial amount of negative skew in the distribution of scores (established by the median sitting in the top third of the box), including a short whisker at the top *versus* a substantially longer one at the bottom. This implies that the tendency for countries of this region to skew into higher-risk territory is constrained, while the reverse is true in the direction of lower risk, resulting in a unique and positive characteristic for the Southwest Pacific region. The only outlier (*i.e.* datapoint falling beyond the whisker) across the global set is registered for the Europe region and is provided by Russia. Had Russia been considered an Asian country, it would still have figured in the upper reaches of the top whisker – underlining the magnitude of Russia's high-risk score.

3.2.4. National top and bottom performers by region

Scores for all component indicators, as well as resulting internal, external and overall country risk scores are provided in Appendix B. Appendix D provides a global country ranking for each of the three risk categories. Table 5 provides the top and bottom three national

[20] Represented by the colored box in the graph, containing the middle 50% of country scores, falling equally above and below the median (or ranging from the 25% percentile to the 75% percentile).

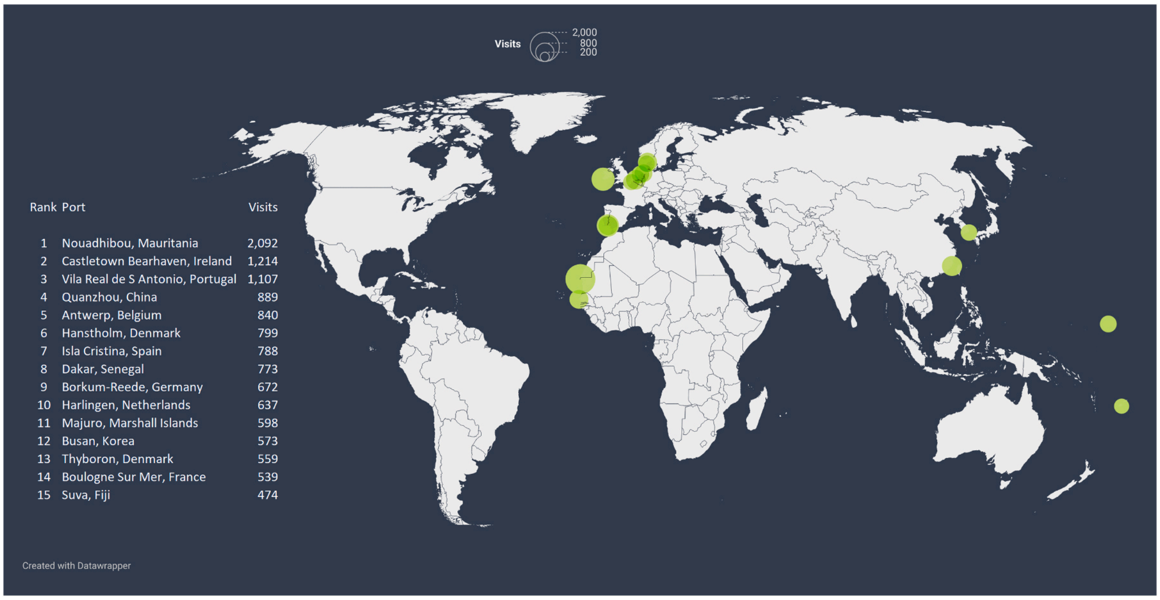

Fig. 7. Top 15 global ports for total foreign catcher vessels by no. of visits.

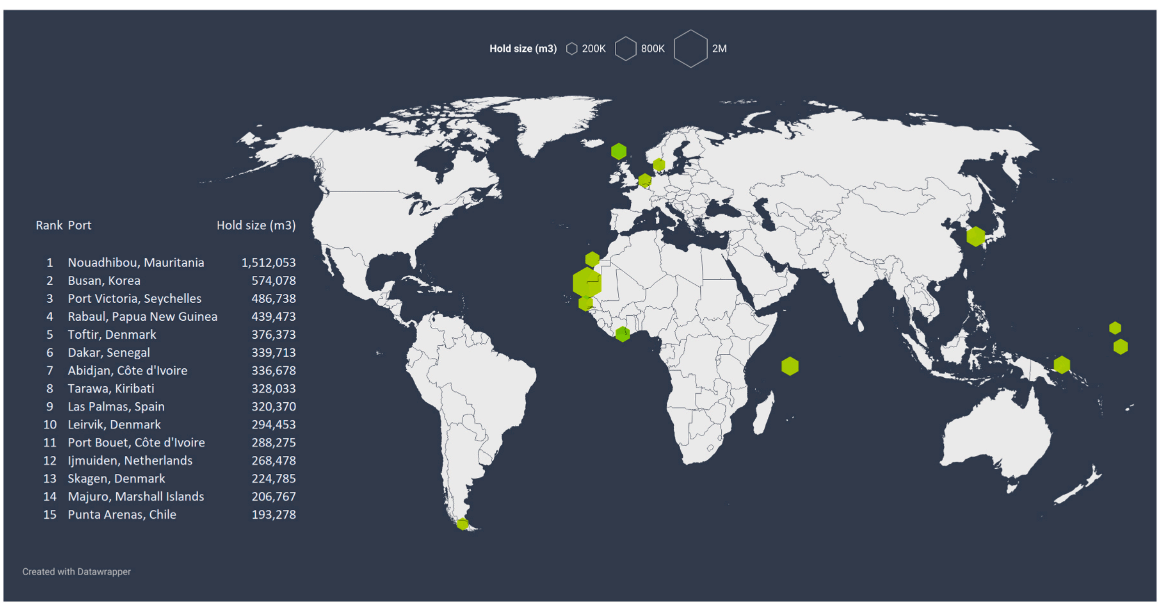

Fig. 8. Top 15 global ports for total foreign catcher vessels by hold size (m^3).

performers across the three risk categories by region.[21] These results are indicative and must be considered carefully in conjunction with the caveats on country rankings indicated in the methods section. However, top and bottom-ranked port States will invariably be separated by substantial gaps within the respective risk categories.

These regional results can only be appraised within the context of individual regions, as the bottom three performers in one region could achieve nominal scores close to top three performer scores in another. For overall risk, bottom performers in Asia and Europe remain China and Russia, unchanged over earlier results.

In the Southwest Pacific, Kiribati, Papua New Guinea and the Solomon Islands remain in the group of highest overall risk port States, while the Cook Islands and Vanuatu remain amongst the lowest risk port States, all mirroring earlier results. In Europe and North America, Sweden – which figured amongst the top three performers across all three risk categories in 2019 – disappears from the top three entirely along with Romania, and is replaced by Finland and Cyprus, while Belgium remains in the top three for overall lowest risk.

In Asia, Sri Lanka retains its 2019 top rank for overall lowest score and is now one of the few countries worldwide figuring in the top three of its region across all three risk categories. This reflects Sri Lanka's remarkable performance in combatting IUU fishing within the group of Asian nations, also detected in another paper using a wider range of IUU mitigation indicators [18]. In Africa, all top and bottom performers have changed over 2019 results, except for the Congo (DRC), retaining its position as the weakest regional performer.

[21] Note that Nicaragua and Bahrain are only ranked under internal and overall risk score, in order not to falsify the rankings owing to their external risk score being 1.0 – derived from zero foreign vessel visits. The two North America region countries are included in the Europe region, to avoid biased results owing to the limited number of countries in this region.

Fig. 9. Top 15 global ports for total foreign reefers by no. of visits.

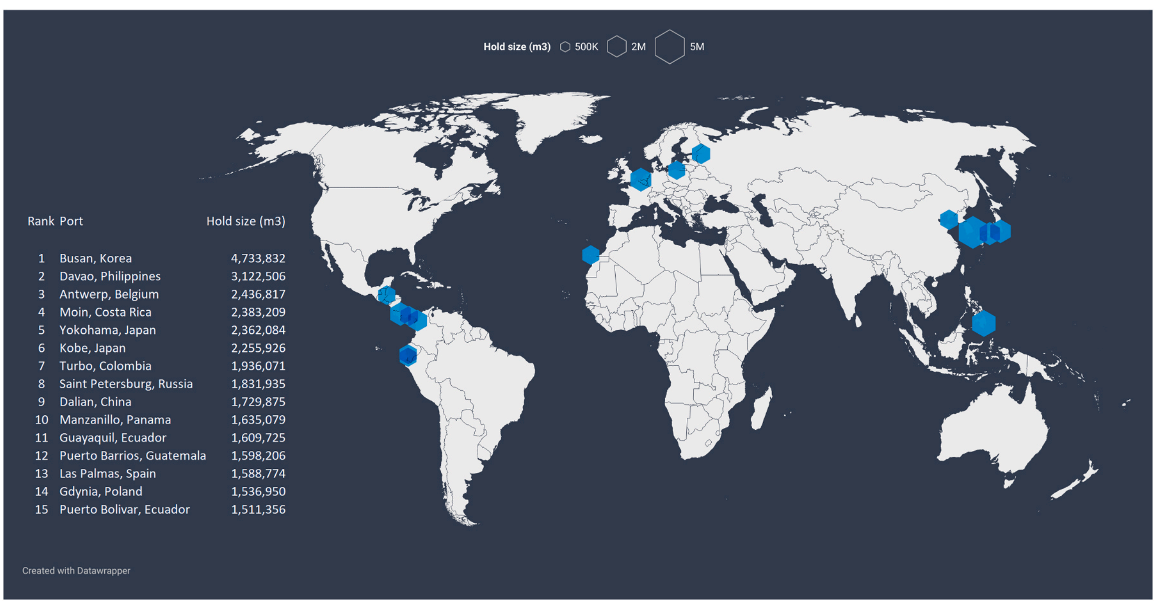

Fig. 10. Top 15 global ports for total foreign reefers by hold size (m^3).

3.2.5. Relationship between internal and external port State risk

Fig. 15 shows the relationship between external and internal risk score, with internal risk used as the independent variable. Countries not operating ports and those doing so, but not having received foreign AIS-fitted vessels, were eliminated from this dataset (n = 138). Regression analysis results in a significant correlation where $p < 0.0005$, and the slope is 0.2608. This correlation was non-significant in the 2019 study, signaling a turn in port risk dynamics. A firm causal relationship between the two variables is now given, first hypothesized in 2019. This implies that, globally, fishing vessels with higher-risk operational profiles tend to call into foreign ports with weaker (*i.e.* higher) port State risk scores. This finding is further characterized directly below.[22]

3.2.6. Internal and external risk score difference between parties and non-parties to the PSMA

The analysis shown in Fig. 16 yields several results. All coastal States with no AIS-vessel entries, plus two port States with no foreign AIS-vessel entries were excluded from the analysis (n = 138). Firstly, it shows two State clusters (in green & orange), being those of countries that had become a party to the PSMA by the 1st of January 2020 (85), and those not having done so by the same date (53). Almost two thirds (61.2%) of port States had signed the PSMA by early 2020, signaling significant and sustained progress over three years earlier (52.9%). Internal risk in this dataset was adjusted by eliminating the PSMA party indicator (#3) as a component, as this indicator naturally contributes to separating the two clusters, generating confirmation bias.

Fig. 16 shows the two cluster averages as green and orange crossed squares. A two-sample T-test finds that the difference along both x and y axes is statistically significant, with respective p values of < 0.0055 and < 0.0014. These results are summarised in Table 6, alongside 2019

[22] Data points in Fig. 5 do not align with those in Fig. 6 because internal risk in Fig. 6 is adjusted and will make points shift along the x-axis – but their position against the y-axis is not affected.

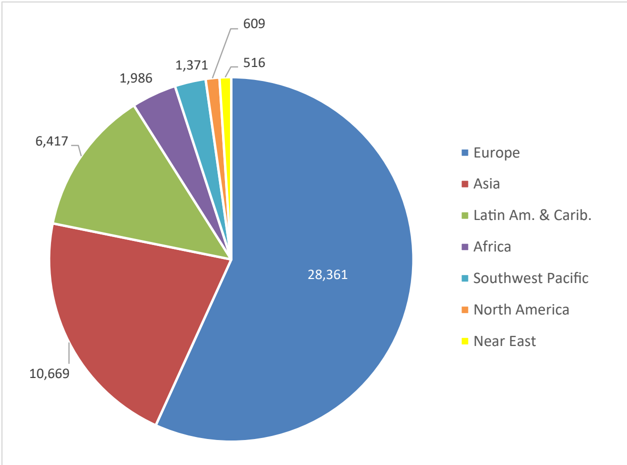

Fig. 11. Distribution of 2020 vessel entries into foreign ports globally, with flag States grouped into seven world regions.

study results. The significance (p-values) of the respective averages has grown considerably. While significance of the difference in external risk between both groups was the weakest in the 2019 study, it is now the most significant. The relative distance of the average external risk between both clusters was 2.78% in the 2019 study, and had grown to 7.52% by 2020 – constituting a 2.7 fold relative increase over the three-year period. Interestingly, this gap has widened almost exclusively at the expense of external risk in the non-PSMA cluster (2.66 *vs* 2.52), while it has remained almost level in the PSMA cluster (2.46 *vs* 2.45). While the relative distance of the average internal risk between both clusters has also grown, this increase was more limited, and to the opposite of external risk evolution the widening of the gap owes primarily to a drop of internal risk in the PSMA cluster (2.09 *vs* 2.12). In summary, the key developments over the three-year period are that external risk in the non-PSMA cluster rises, while internal risk in the PSMA cluster drops to a small degree. Fig. 16 also provides the linear regression lines of both clusters. The correlation between risk factors in the non-PSMA group (in red) is significant ($p = 0.011$), while that of the PSMA group (in green) is not ($p = 0.193$).

3.2.7. Relationship between port State IUU risk and its corruption perceptions index (CPI) score

The analysis underpinning Fig. 17 tests the relationship between corruption – one of the constituent factors of wider quality of governance indicators – as the independent variable, and risk scores (internal, external and overall) as the dependent variable. This analysis had also been run in the 2019 study and had yielded mixed results. All coastal States with no AIS-vessel entries, and/or no CPI scores, plus two port States with no foreign AIS-vessel entries were excluded from the analysis (n = 127). Given that the CPI is a component of both internal and external risk, it was eliminated as a component indicator from both internal and external risk and resulting overall risk, for this analysis, to eliminate confirmation bias.

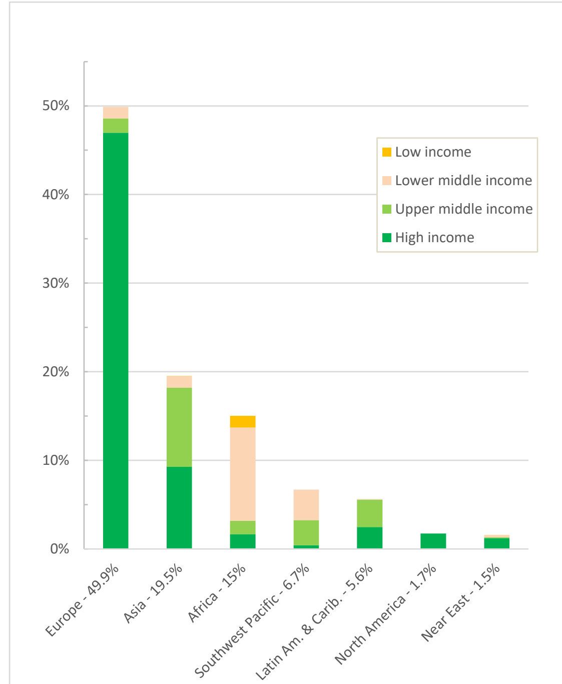

Fig. 13. Relative contribution of foreign vessel entries into ports of a region and distribution of ports by port State income group.

The regression analysis results in three significant correlations of risk score with the CPI score, as follows: internal risk ($p = 0.0005$), external risk ($p = 0.0077$), overall risk ($p < <0.0001$). CPI scores work in the opposite direction to IUU risk scores; the higher the CPI score, the better the performance of the State. The findings establish a significant inverse

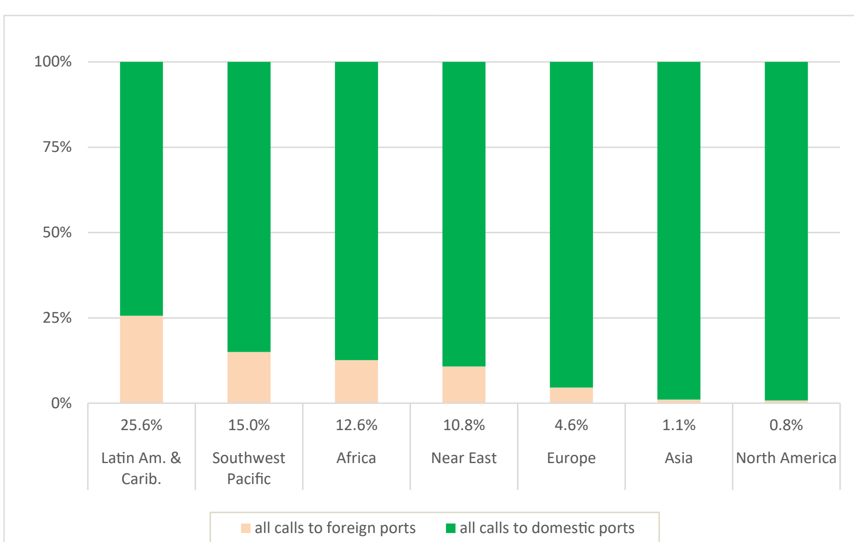

Fig. 12. Distribution between domestic and foreign port visits by flag states arranged into regions.

Table 3
Evolution of global port State risk by category between 2017 and 2020.

Year of dataset	Internal risk score	External risk score	Overall risk score
2017	2.299	2.479	2.404
2020	2.226	2.517	2.383
Difference (in %)	**-1.83%**	**+ 0.96%**	**-0.52%**

correlation between the CPI score, at all three risk levels. Internal risk correlates strongest with the CPI, while external risk correlates less strongly – albeit remaining highly significant.

3.2.8. Relationship between vessel flag State and port State CPI scores

Fig. 18 shows the relationship between the average CPI score of flag State vessels visiting plotted against the CPI score of the port States visited. All coastal States with no AIS-vessel entries, and/or no TI scores, plus two port States with no foreign AIS-vessel entries were excluded from the analysis (n = 127).

Regression analysis produces a highly significant positive correlation between these two variables ($p < <0.0001$), where the CPI score of the port State is used as the independent variable, confirming the result obtained in the 2019 study. The polynomial regression line serves the purpose of revealing the subtler trend inherent to this dataset, as the regression analysis reveals non-linear distribution of residuals. The correlation yields a mild exponential-type behavior, providing a flatter trend (weaker correlation) in the lower CPI range, and then a clearly up-ticking trend (stronger correlation) from the mid-CPI range forwards.

3.2.9. Relationship between overall port State IUU risk and per capita gross national income

The 2019 study assessed the relationship between overall regional port State risk against the four World Bank income groups,[23] finding that in general risk declined with rising income within regional groups but found the Near East defied this global trend by trending in the opposite direction, and with Asia arising as the only region trending flat. Since the 2019 statistics were descriptive only, we ran overall port State risk scores individually against the finer 2020 per capita gross national income (PPP) indicator,[24] testing global and regional correlations, to establish the statistical significance of any countervailing regional trend signal(s) emerging in the 2020 dataset.

In this analysis, North America – consisting of only two countries – is

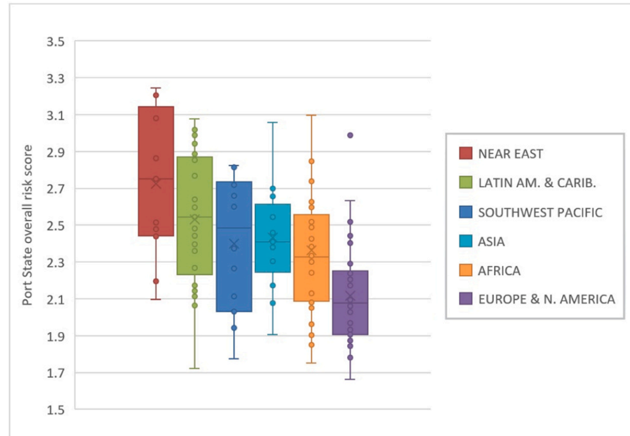

Fig. 14. Distribution of overall port State risk scores within and between world regions.

merged with Europe, as it does not avail itself to regression analysis based on its limited number of countries.[25] Coastal States with no AIS-based port movements (13) were eliminated from the set ($n = 140$). For five countries the World Bank dataset did not list GNI per capita PPP data,[26] and in those cases they were sourced from two alternative websites, providing reasonable alternatives.[27] In one case where the 2020 World Bank figure was not available, the 2019 figure was used instead (Kuwait), and in another case, a figure from a government website was computed for 2019 (Cook Islands).[28] Table 7 provides the results of the regional and global regression analyses, with the global analysis in the top row, followed by regional regressions with the significance of correlation in descending order.

Globally, the negative relationship between per capita GNI and risk is significant ($p = 0.022$). Risk decreases with rising per capita income, yielding a negative slope. The same trend is verified for all world regions, though only for one in a statistically significant manner (*i.e.* Southwest Pacific region), and with the exception of the Near East region, where the slope is positive, scatter in the data is the most limited across the 7 regressions (R^2 =0.402), and the significance of the relationship is the strongest across the 7 regressions ($p = 0.02$) – including the global one. This establishes a statistically highly significant corre-

Table 4
Ranking of world regions by risk category.

Rank	Internal risk score		External risk score		Overall risk score	
1	North America	1.88	Europe	2.34	Europe	2.12
2	Europe	1.89	Southwest Pacific	2.36	North America	2.13
3	Africa	2.19	North America	2.38	Africa	2.36
4	Asia	2.29	Africa	2.54	Southwest Pacific	2.40
5	Latin Am. & Carib.	2.38	Asia	2.58	Asia	2.43
6	Southwest Pacific	2.44	Latin Am. & Carib.	2.64	Latin Am. & Carib.	2.53
7	Near East	2.53	Near East	2.74	Near East	2.72

[23] A country can belong to either the low income, lower middle-income, upper middle-income, or high-income group.

[24] GNI per capita, PPP (2020). This indicator provides per capita values for gross national income (GNI. Formerly GNP) expressed in current international dollars converted by purchasing power parity (PPP) conversion factor. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. PPP conversion factor is a spatial price deflator and currency converter that eliminates the effects of the differences in price levels between countries. (Source: World Bank)

[25] A sensitivity analysis was carried out, establishing that the integration of North America data into the Europe region dataset was the integration that had the least impact on outcomes, verifying contiguous data behavior.

[26] Cuba, North Korea, Taiwan, Venezuela, and Yemen

[27] Source: https://www.nationsonline.org/oneworld//GNI_PPP_of_countries.htm and https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita. While these data provide a rougher approximation to the current 2020 GNI per capita PPP, including them in the analysis is more robust than leaving them out altogether, especially for regions with fewer countries.

[28] Source: https://www.mfem.gov.ck/statistics/economic-statistics

Table 5
Top & bottom performers across port State risk categories.

	Region	Internal risk score	External risk score	Overall risk score
Top 3 (starting with the strongest)	**Africa**	S. Tome & Principe	Kenya	Gambia
		Senegal	Gambia	Kenya
		Gambia	Tanzania	Cabo Verde
	Asia	Maldives	Sri Lanka	Sri Lanka
		Sri Lanka	Myanmar	Maldives
		Japan (+1)[a]	North Korea	Singapore
	Europe & N. America	Lithuania	Finland	Finland
		Belgium	Estonia	Belgium
		Finland	Cyprus (+1)[b]	Cyprus (+1)[c]
	Latin Am. & the Caribbean	Barbados	Bahamas	Bahamas
		Bahamas	Mexico	Nicaragua
		Cuba	Brazil (+1)[d]	Trinidad & Tobago
	Near East	Oman	Djibouti	Djibouti
		Libya	Iran	Oman
		Egypt (+1)[e]	Lebanon (+1)[f]	Libya
	Southwest Pacific	Cook Islands	Cook Islands	Cook Islands
		Australia	Palau	Palau
		New Zealand	Tonga (+1)[g]	Tonga (+1)[h]
Bottom 3 (starting with the weakest)	**Africa**	Congo (DRC)	Sudan	Congo (DRC)
		Cameroon	S. Tome & Principe	Nigeria
		Congo, R. of	Ghana	Guinea-Bissau
	Asia	North Korea	China	China
		China	Thailand	Viet Nam
		Viet Nam	Philippines	Malaysia
	Europe & N. America	Russia	Montenegro	Russia
		France	Russia	Israel
		Israel	Croatia	Montenegro
	Latin Am. & the Caribbean	Suriname	El Salvador	Dominican Rep.
		Dominican Rep.	Saint Kitts & Nevis	Colombia
		Colombia	Barbados (+3)[i]	Saint Lucia
	Near East	Bahrain	Kuwait	Qatar
		UAE	Qatar	Bahrain
		Qatar	Saudi Arabia	Kuwait
	Southwest Pacific	PNG	Samoa	Kiribati
		Kiribati	Kiribati	PNG
		FSM (+1)[j]	Tuvalu (+1)[k]	Solomon Isl. (+1)[l]

[a] Singapore;
[b] Germany;
[c] Estonia;
[d] Trinidad and Tobago;
[e] Lebanon;
[f] UAE;
[g] Vanuatu;
[h] Vanuatu;
[i] Dominican Republic, Guyana, Saint Lucia;
[j] Solomon Islands;
[k] New Zealand;
[l] FSM.

lation for the Near East, detected in the 2019 study, consisting of a steady rise in overall port State risk with rising national income.

Fig. 19 provides a visual impression of the overall port State average risk for world regions when plotted against per capita GNI. The figure shows how the Near East and the Europe regions are maximally separated by their respective average overall port State risk scores, while at the same time providing the second and third most affluent world regions.

3.2.10. *Analysis of designated port usage in ports of PSMA parties*

Directly gauging the effectiveness of the PSMA in curbing IUU fishing has thus far remained hard to determine.[29] One simple test to determine PSMA effectiveness is to assess how the designated ports rule is implemented in practice. 85 port States had become a party to the PSMA by the 1st of January 2020, and 32 of these (37.6%) had also designated and listed their fishing ports[30] on FAO's publicly hosted PSMA database.[31] For these 32 port States, the analysis to follow establishes what fraction of AIS-detected foreign vessel visits were made to designated ports, and what fraction was made to non-designated ports. Obtained results reveal how consistently the designated port entry rule was applied by port States that had fully adopted and were understood to be implementing the PSMA by January of 2020.

Given the special treatment the EU provides to member State vessels when entering the port of another EU member State – considering such movement to be domestic, rather than foreign[32] – the table presenting the results of this analysis is split into two separate tables, with Table 8 covering eighteen EU port States, providing a set of more detailed statistics responding to its special regulatory framework, and Table 10 covering all others.

Table 8 reveals that there are very large discrepancies between EU member States regarding the implementation of the designated port entry rule as applying to foreign non-EU vessel visits. In Belgium, only 2 out of the 147 AIS-detected foreign non-EU vessels (1.36%) called into a designated port in 2020, while 269 out of 275 foreign vessels (97.82%) did so in the neighboring Netherlands. In some EU port States, the usage rate of ports between non-domestic EU and foreign fleets can be largely similar (*e.g.* Ireland or the Netherlands), while in others non-domestic EU vessels have a greater tendency to visit non-designated ports. The exceptions to this latter trend are Belgium, Denmark and France, where non-domestic EU fleets have a much higher tendency to call into designated ports than foreign vessels. On an EU-wide basis, the fraction of foreign non-EU vessels calling into designated ports is about the same as that of non-domestic EU vessels. Overall, for 2020, the fraction of foreign vessels flagged outside of the EU calling to non-designated EU ports was 46.6% – *i.e.* close to 1:2 vessels.

A related finding arose during this analysis, which used the designated ports list communicated to FAO and publicly hosted on FAO's statutory PSMA interface (see footnote 34). The EU also publishes a list of designated ports independently under EU legislation.[33] Table 9 reproduces the number of ports listed under both sources at the time the EU legislation was published (February 2020). The simple comparison reveals that for the 22 full EU port States listed under EU legislation, five port States (or 23%) present information inconsistencies between records. Disparities relate to information being incomplete in the FAO repository (Italy, Netherlands, Spain and Portugal), information being incomplete in the FAO repository and conflicting between repositories (Portugal), information simply not being submitted to FAO (Malta), or in the case of France, the FAO repository listing more designated ports than the EU legislation.

[29] See for instance: https://chinadialogueocean.net/en/fisheries/port-state-measures-agreement-treaty-aims-to-end-illegal-fishing-explained/ (May, 2022)
[30] For these 32 States, fishing ports had been designated by the 1st of January 2020, and none were added over the course of 2020. Port States not fulfilling these two conditions were eliminated from the overall sample. As an example, Canada was eliminated from the final sample because it designated further ports in mid-2020, following ports designated earlier in 2019.
[31] Source: https://www.fao.org/fishery/port-state-measures/psmaapp/?locale=en&action=qry
[32] EC No. 1005/2008, Articles 4(2), 5(1) and 5(2).
[33] Official Journal of the European Union [12] *List of ports in EU Member States where landings and transhipment operations of fishery products are allowed and port services are accessible for third country fishing vessels, in accordance with Article 5 (2) of Council Regulation (EC) No 1005/2008*. Notices from member States. 2020/C 51/05. 14.2.2020.

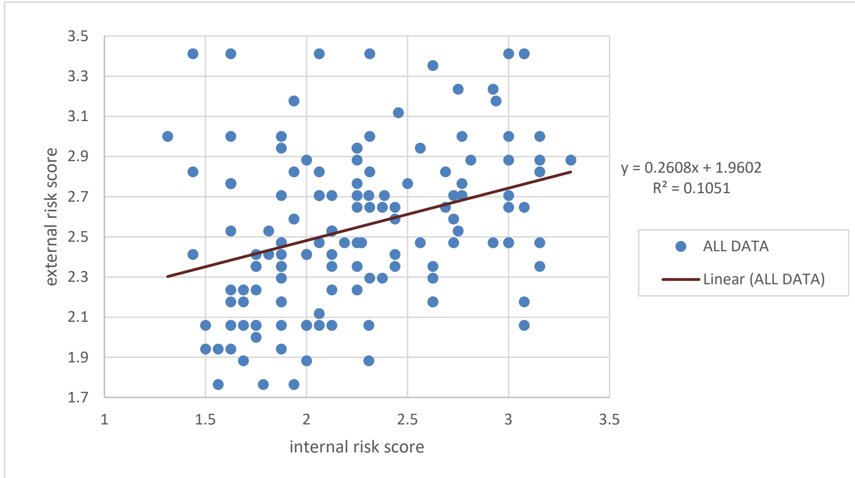

Fig. 15. Relationship between internal and external port State risk.

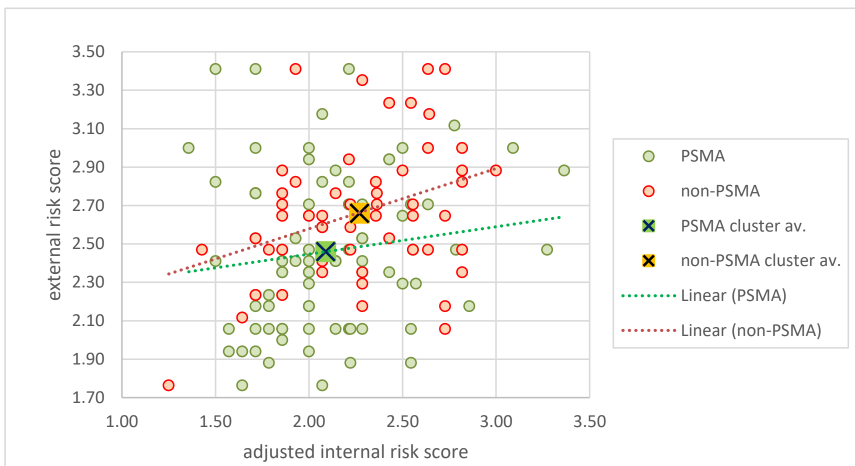

Fig. 16. Comparing average internal and external risk scores for PSMA party and non-party port State clusters.

Table 6
Comparative assessment of average cluster distance in 2017 and 2020 datasets.

		PSMA cluster av.	non-PSMA cluster av.	*p*-value	Rel. distance between pairs
2017	internal	2.12	2.28	0.017	7.02%
2020	risk	2.09	2.27	0.005	7.93%
2017	external	2.45	2.52	0.045	2.78%
2020	risk	2.46	2.66	0.001	7.52%

Table 10 lists the results for the fourteen non-EU PSMA parties, and foreign vessel calls to their ports. Generally, and with some notable exceptions, it appears that less affluent, but important fishing Nations (*e.g.* Ghana, Maldives, Seychelles) yield very high designated port use rule implementation results, while notable developed fishing Nations (*i.e.* Japan, Iceland and Norway) fall short of expectations. Overall, this group of 14 globally distributed port States also yields a sensibly higher average of designated port use figure (60.4%) than the group of EU port States (54.40%), indicating that EU port States face the overall more important implementation challenges in this domain.

4. Discussion

4.1. Port rankings and contrasting with 2019 study findings

A review of ports ranked by total visits shows that just as in the 2019 study, China and Chinese ports predominate, largely owing to China's large distant water fishing and domestic fleets. Looking beyond China, while the exact ranking differs slightly and the overall number of port visits is greater in the present paper, many of the same ports catering to foreign fleets maintain their top 15 ranking. In some ways this is striking given that the Covid-19 pandemic is known to have had considerable impact on global travel and shipping patterns and was expected to have had a major impact on port visits patterns. That said some pandemic related shifts are apparent, such as reduced visits to ports in several States in the Pacific where most countries closed borders and limited access. Majuro, Republic of Marshall Islands, a major tuna transshipment hub that significantly limited port access during the height of the pandemic showed a considerable decline in port visits. Other important regional tuna hubs including Suva, Fiji, Port Louis, Mauritius, Manta, Ecuador, Pohnpei, Federated States of Micronesia, and Abidjan, Cote d'Ivoire also showed a reduction in port visits, likely because of pandemic related restrictions.

On the other hand, other ports, such as the port of Nouadhibou, Mauritania, showed a considerable increase in port visits compared to the 2019 study, moving from a 5th place ranking 2019 to a 1st place

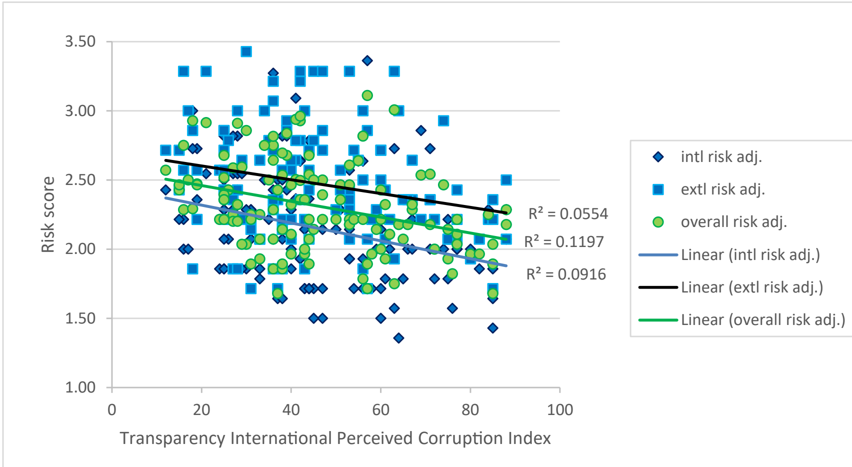

Fig. 17. Relationship between port State risk and perceived corruption.

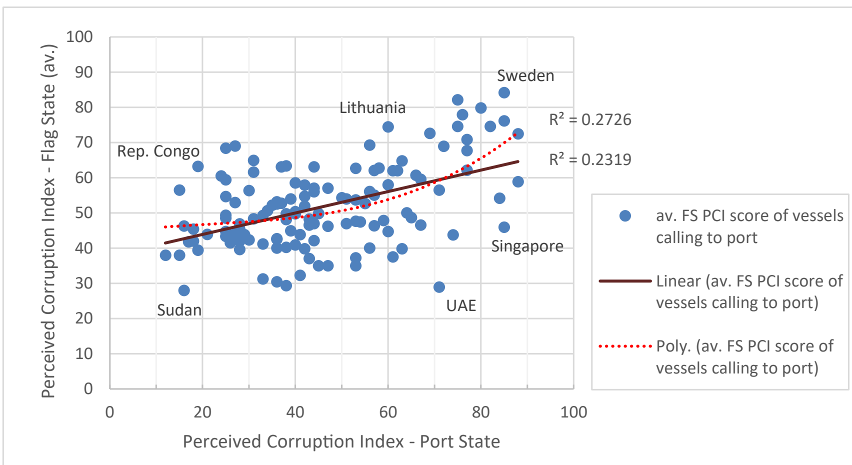

Fig. 18. Relationship between flag and port State CPIs.

Table 7
Regression statistics of overall port State risk scores *vs* GNI per capita, PPP (2020), globally and by region.

Region	*n*	slope	intercept	*p*-value (*F*)	R^2 linear
Global	140	-3.63E-06	2.46	0.02235	0.03724
Near East	13	+ 9.17E-06	2.44	0.02005	0.40155
Southwest Pacific	14	-1.23E-05	2.58	0.04212	0.30118
Europe & North America	34	-5.99E-06	2.36	0.06090	0.10549
Africa	33	-8.63E-06	2.42	0.35230	0.02796
Asia	17	-2.41E-06	2.48	0.46736	0.03575
Latin America & the Caribbean	29	-6.29E-06	2.63	0.52491	0.01514

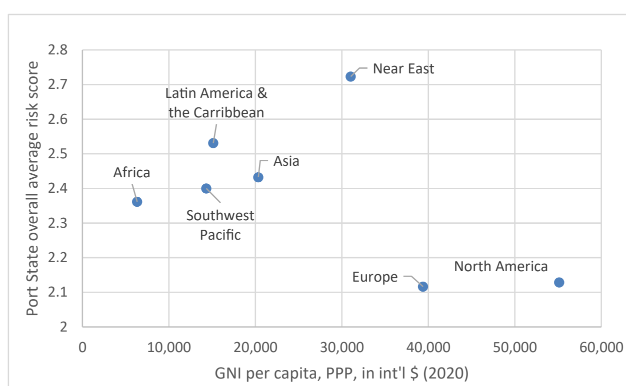

Fig. 19. Relationship between regional overall port State risk and GNI per capita (PPP).

ranking in the present paper, based on foreign catcher hold size (3-fold increase). In this case, it appears that the shift is more related to national policies seeking more landings and/or transshipments domestically of resources exploited in the national EEZ, rather than to dynamics generated by the pandemic.

4.2. Evolution of port State risk

The broader port State risk analysis shows that overall, the PSMA – through its narrow focus on foreign vessel port entries – did not apply to 97.1% of global commercial fishing vessel port calls in 2020. This is exacerbated by the fact that the EU treats EU vessel calls into ports of other EU member States as domestic calls, bringing the above figure close to 97.9% when adding and applying this EU-specific perspective. This finding is corroborated by [29], stating that overall "*fishing vessels carry out a limited number of foreign calls* […]". Given the fact that globally, a large portion of smaller commercial vessels are not yet equipped with AIS and are more likely to call into national rather than

Table 8
Port entry statistics for 18 EU port States in 2020.

EU Port State	Total no. of (non-domestic) EU vessel calls	Total no. of foreign (non-EU) vessel calls	No. of (non-domestic) EU vessel calls into designated ports *	No. of foreign (non-EU) vessel calls into designated ports	(Non-domestic) EU vessel calls into designated ports (in %) *	(Non-EU) foreign vessel calls into designated ports (in %)
Belgium	951	147	110	2	*11.57*	*1.36*
Bulgaria	0	1	-	1	-	*100.00*
Croatia	5	2	1	1	*20.00*	*50.00*
Cyprus	15	0	3	-	*20.00*	-
Denmark	2,616	1,167	1,773	510	*67.78*	*43.70*
Finland	9	0	0	-	*0*	-
France	1,298	95	958	16	*73.81*	*16.84*
Germany	1,375	45	155	23	*11.27*	*51.11*
Greece	352	23	20	4	*5.68*	*17.39*
Ireland	1,699	27	1,376	26	*80.99*	*96.30*
Italy	141	28	43	26	*30.50*	*92.86*
Latvia	355	9	181	8	*50.99*	*88.89*
Lithuania	70	43	70	43	*100*	*100*
Netherlands	2,092	275	1,178	269	*84.99*	*97.82*
Poland	75	126	47	118	*62.67*	*93.65*
Portugal	1,223	8	93	2	*7.60*	*25.00*
Romania	21	0	0	-	*0*	-
Sweden	386	107	129	95	*33.42*	*88.79*
TOTAL	**12,683**	**2,103**	**6,737**	**1,144**	***53.12***	***54.40***

* Note that EU law does not currently require vessels from another EU State to use a port designated under the PSMA.

Table 9
Designated ports listed for 22 EU port States in early 2020.

EU Port State	No. of ports listed in EU legislation	No. of ports listed in the FAO PSMA database	Result	Notes
Belgium	2	2	✔	
Bulgaria	2	2	✔	
Croatia	4	4	✔	
Cyprus	1	1	✔	
Denmark	11	11	✔	
Estonia	none	none	✔	
Finland	1	1	✔	
France	23	24	✖	1 additional overseas port on FAO list
Germany	4	4	✔	
Greece	2	2	✔	
Ireland *	2	2	✔	
Italy	18	16	✖	2 ports missing on FAO list
Latvia	2	2	✔	
Lithuania	1	1	✔	
Malta	1	0	✖	No port communicated to FAO
Netherlands	6	6	✔	
Poland	4	4	✔	
Portugal	11	9	✖	Ports not matching between lists, some in one and not in the other & *vice versa*, and some ports amiss
Romania	1	1	✔	
Slovenia	none	none	✔	
Spain	24	23	✖	Ports communicated to FAO in first half of 2020; 1 port missing on FAO list (added later in mid-2021)
Sweden	17	17	✔	

* Northern Ireland, falling under the Protocol on Ireland/Northern Ireland of the Agreement on the withdrawal of the United Kingdom of Great Britain and Northern Ireland from the European Union and the European Atomic Energy Community, has been omitted as not listed independently in FAO PSMA database.

Table 10
Port entry statistics for 14 non-EU port States in 2020.

Port State	Total no. of foreign vessel visits	No. of foreign vessel visits to designated ports	Foreign vessel visits to designated ports (in %)
Australia	63	55	*87.30*
Chile	282	261	*92.55*
The Gambia	30	30	*100.00*
Ghana	170	170	*100.00*
Iceland	258	217	*66.51*
Japan	1,554	528	*38.05*
Kenya	10	10	*100.00*
Maldives	16	16	*100.00*
New Zealand	134	123	*91.79*
Norway	1,738	1,059	*60.93*
São Tomé e Principe	2	2	*100.00*
Seychelles	343	343	*100.00*
Togo	58	58	*100.00*
Vanuatu	59	49	*83.05*
TOTAL	**4,717**	**2,849**	***60.40***

foreign ports, the PSMA and its ruleset applied to less than 2% of all commercial port calls globally in 2020. This raises the question whether the decision to focus the binding remit of the PSMA's article 3 ("Application") to foreign vessel port entries was a judicious call, and whether this will risk undermining the effectiveness of the instrument in coming years. National legal frameworks setting out to apply the PSMA framework in equal measure to both foreign and domestic fleets, as now legislated for by Ecuador,[34] embody one option to overcome the narrow interpretation of article 3 para 1, binding in its stated principles of fairness, transparency and non-discrimination of article 3 para 4, thus expanding the reach and the bite of the Agreement.

In the Southwest Pacific, about half of all foreign calls are made into lower middle-income port States. For this region, where the positive relationship between national income level and the effectiveness of combatting IUU fishing generally has been established in the past [18] and in ports specifically (this paper), comparative risk associated with capacity constraints in duly applying PSMA measures are highest in this region. Conversely, for regions where the relationship between income

[34] Personal communication. Mr. Andrés Arens, Vice-Minister of Aquaculture and Fisheries, Ecuador. May, 2023.

and effectiveness of combatting IUU fishing is inversed – as is the case for the Near East, established in this paper (Table 7) – it is port entries into the advanced economies across this region that are driving comparatively higher risk of IUU-tainted landings.

Globally, overall port State risk has dropped marginally over the previously established figure (2019 study), from 2.404 to 2.383 (−0.52%). This decrease is fueled by a stronger decrease of internal risk (−1.83%), and counter-balanced by a rise in external risk (+0.96%). Overall, most regions have improved. The results show that external risk evolution yielded most mixed results, to the opposite of internal risk where all but one region had improved scores. This provides a first set of trends across these two studies that may serve as a benchmark for future updates.

The global analysis presented in Table 4 on the ranking of regions by risk category singles out Latin America & the Caribbean and the Near East as the only world regions with substantially weakening overall scores, both driven largely or entirely by their weakening external risk scores. This finding confirms the Near East's overall weak support of the PSMA, with only three out of 15 countries having become a party, and zero designated ports registered on the FAO database by mid-2022 – the weakest standing of any region by far. Given the global weakening of external risk (Table 3), it appears that these two world regions attracted the brunt of high-risk vessel traffic diversions that have taken place in the wake of the wider and more consistent PSMA adoption and implementation, and diversions that resulted from the Covid-19 pandemic.

4.3. Port State performance

Russia and China remain put as the highest risk port States in the Europe and Asia regions, the two most important regions in terms of fleet sizes, catch volumes, vessel entries into foreign ports, and foreign vessel entries into ports of these two regions [13]; this paper). China and Russia scores directly mirror their bottom-ranking positions in the *2021 IUU Fishing Index Report* [24].[35] In the Near East, only high-income countries now supply the three highest overall risk port States – one up over 2019 results. In addition to this, these three bottom performers all have relatively high (*i.e.* good) CPI scores also.

Internal and external risk now correlate strongly (they did not in the 2019 study), implying that external risk drops alongside improvements in managing PSMA matters. However, the detailed analysis shows that this dynamic differs between the group of parties to the PSMA and the group of non-parties. While the difference between internal and external risk has grown significantly between both groups since 2019, results show that for external risk this owes almost entirely to non-parties facing higher external risk, while for internal risk it owes almost entirely to PSMA parties improving internal port State risk. The analysis also reveals that the correlation between internal and external risk is only significant in the non-party group. The most logical explanation for this counterintuitive finding is that for the group where external port risk only rises marginally with higher internal risk (*i.e.* PSMA-party States), the fact that a port State is a party to the PSMA appears to constitute an inherently potent factor acting to deter higher-risk vessels from visiting such ports. This does not apply to PSMA non-party port States, where the logical and causal relation between internal and external risk remains verified and has strengthened in recent years. The significant relationship between internal and external risk at the global level is hence driven by PSMA non-parties, and the results suggest that higher risk vessels have been pushed to preferentially call into PSMA non-party State ports in recent years – firmly establishing the structuring and transformational influence of the Agreement.

The analysis of the relationship between port State IUU risk and the CPI score of the port State also yields significant results, affirming the corroding influence of corruption – and thus weak governance – on port State performance, with internal port State risk correlating most strongly of the two risk components. Low R^2 values suggest that corruption is but one amongst other significant co-factors driving port State risk. The most conspicuous outlier defying the trend of rising flag State *versus* port State CPI scores[36] (Fig. 18) is the United Arab Emirates. This is reflective of the overall weak standing of affluent Near Eastern countries in combatting and deterring IUU fishing – as established in this paper also.

The relationship between overall port State IUU risk and per capita GNI establishes an overall, and globally significant negative relationship between overall port State risk and income. The higher the income, the lower the overall port State risk. However, the global trend yields very high scatter, meaning that – like corruption, as a proxy of quality of governance – it is but one amongst more co-factors driving port State risk. However, this highlights the need for more developed and affluent PSMA parties to support developing States in improving national capacity to develop and implement effective PSMA measures – as called for in the PSMA.[37]

Of all seven world regions, only the Near East produces an inverse result. It is statistically significant and yields the lowest scatter in any of the regional and global datasets (R^2 =0.40), underlining its potent structuring effect in this region. Africa, Asia and Latin America and the Caribbean are trending close to flat, and yield the highest *p*-values, indicating that port State risk is evolving independently of income in those regions. While this result was already apparent for Asia in the 2019 study, and is verified here, it was not so for Africa, Latin America and the Caribbean.[38]

Overall, national income is a weak predictor of port State performance, producing high scatter and regionally significant lack of correlation, and inversions. The governance-related CPI indicator also produces high scatter, but several times lower than that of per capita income, indicating that quality of governance is a more proximate factor determining port State risk. This is strongly supported by the significant relationship between high-risk vessels tending to visit high risk ports (Fig. 18). Marteache *et al.* [25] obtained a similar result, finding that "*developed and developing economies did not differ significantly in the number of visits made by IUU fishing vessels*", concluding that the "*choice-structuring properties*" of ports that high-risk vessels tend to seek out include a statistically significant preference for countries with weaker governance.

Hence, regarding the relationship between port State risk on one hand, and the quality of governance and national income on the other, this paper shows that effectiveness of port State IUU risk mitigation is not merely a straightforward function of national income and quality of governance. Rather, it depends on national stock-taking in binding global initiatives, political will and interrelated setting of national policy prerogatives, and a resulting consequential implementation of port State measures. These processes are driven by other potent co-factors relating to social, economic and cultural influences, shared to differing degrees between countries of same regions [18]. This implies that world regions do not all "tick the same", and can yield vastly different results, even when some of the bases they are founded upon – *e.g.* income and/or quality of governance – are comparable. While many studies have investigated economic and institutional factors driving IUU fishing (*e.g.* [23]; [25]; [22] – fewer studies have explored regional historic, social, cultural and related behavioral factors driving IUU fishing [6], conditioning national responses to law enforcement and combatting of IUU fishing in particular [4]. Existing studies touching on these latter

[35] Access online interactive also: https://www.iuufishingindex.net/

[36] Port State CPI score of 71, and < 30 average flag State CPI of visiting foreign fishing vessels.

[37] See: PSMA Article 21 "Requirements of developing States".

[38] Note that the 2019 study used the four World Bank national income brackets as a metric, rather than per capita GNI, which will likely explain some of the detected discrepancies.

domains are often limited to a narrower – albeit pertinent – focus on the influence of "*legal culture*" in law enforcement practices and outcomes (*e.g.* [32]).

For 32 port States party to the PSMA and available for assessment, we find that overall, the implementation of the PSMA's designated port use rule for foreign vessel visits, four years after the coming into force of the PSMA, is ineffective at the global level. Champions mainly arise among developing Nations – many of which important fishing Nations – often limiting foreign vessel entries entirely (100%) to designated ports, while poor performers are mostly large and developed fishing Nations where more than half of all foreign vessel entries may occur into non-designated ports. These findings intimate a clear lack of consistent application of the PSMA framework in relation to this central PSMA mechanism – across developed economies.

It has been documented for years that there is a lack of harmonization between EU member States in monitoring and enforcing EU fisheries law [3,35,7-9], having resulted, *inter alia*, in documented intra-EU country-of-seafood-import diversions as a function of export country "carding" status,[39] so as to minimize IUU-product detection risk [28]. This paper shows that discrepancies also exist in the implementation of the designated port entry rule for foreign vessels into EU member State ports. These movements generally serve a direct seafood import function. EU policy and law treating non-domestic EU vessel entries the same as domestic port calls, limiting "*an effective scheme of inspections in port*" to third country fishing vessels [11],[40] and providing for a "*non-discriminatory approach*" to control, inspection and enforcement of intra-EU sectors, vessels and persons [10],[41] is therefore inherently risky and could be construed as dodging the strictures of the PSMA – which clearly discriminates between vessels along the foreign/domestic axis.

In light of the EU IUU Regulation setting out to identifying and sanctioning any third country[42] for "*failing to discharge the duties incumbent upon it under international law as flag, port, coastal or market state, to take action to prevent deter and eliminate IUU fishing*"[43] – therein also targeting the failure of foreign port States to implement their duties under the PSMA – it is surprising to find that the EU, as a group of port States, currently arises, ostensibly, as the weakest global implementer of the designated port entry rule. The EU IUU Regulation is understood not only as a mechanism to promote the conservation and management of marine living resources, but as "*a mechanism to level the playing field between EU operators and third-country (non-EU) operators*", to prevent that "*third-country vessel will gain an 'unfair advantage' by operating under the legislation of a state perceived by the EU to be acting inconsistently with its international obligations to prevent, deter and eliminate IUU fishing*" [17]. Considering this, and the long-arm jurisdiction-type powers it confers upon itself through its IUU Regulation [16], the EU's current overall inconsistent implementation of this critical PSMA mechanism does not mirror its expectations of solid foreign port State compliance in the same domain.

Since all non-domestic EU vessel entries are exempted from the designated port entry rule within EU ports (and thus from the application of the PSMA framework) – some 14,000 vessel calls in 2020 – and that just under half of the 2,103 foreign vessel entries were not subjected to designated port State entry rules, it arises that some 94% of vessel calls that should arguably have been subjected to the PSMA framework, and the designated port entry rule, have in fact been exempted from this for a variety of reasons – including EU legislation currently exempting EU members from applying the PSMA framework with respect to other EU Member State vessels.

Given the Europe region's stellar global performance at the level of its regional overall port State risk score, a region of which the EU is an important component, these findings also underline that the designated port entry rule ought to integrate the port State risk score as an adequately weighted indicator in the future, highlighting that any indicator-based score or index is only as good as the pertinence, the proximity (to the object of enquiry), and the completeness of its component indicators.[44]

5. Conclusions

Port rankings are important to understand the dynamics of port usage by foreign and domestic vessels, both by vessel type (catchers/reefers), and by numbers of visits and total hold size volume catered for by individual ports. These rankings will continue to change, not only as a function of PSMA adoption and related diversion of higher risk vessels and fleets – as established in this paper – but also as a function of ongoing AIS adoption, the differential development of port State business driven by many factors (including climate change) and disruptive regional and/or global events such as the Covid-19 pandemic. Distinguishing between these signals will become easier as AIS adoption advances and/or levels out, and gradually diminishes as a source of intrinsic variability.

This paper establishes that the PSMA framework only applies to a tiny portion (<3%) of total global fishing vessel port calls, domestic and foreign combined, while the EU, as the most prominent block engaging in foreign port calls, operates a ruleset that allows EU port States to treat entries of foreign EU vessels as domestic, and to not subject them to the strictures of the PSMA framework. These factors limit the reach of the PSMA and may undermine its potential and ultimate impact over time. Importantly, the effective implementation of the designated port entry rule in PSMA-party States is verified for many developing economies but is largely not in place in the developed world, with EU port States providing the weakest (<54%) implementation/compliance results globally.

The paper finds that between 2017 and 2020, PSMA parties improved procedures related to port State measures– leading to a measurable drop in internal risk – while external risk remained level. The opposite is true for PSMA non-parties, where internal risk remained level (*i.e.* no PSC improvements), and external risk rose sharply. The related analysis suggests that PSMA adoption alone is a potent deterrent to high-risk vessel calls, and that higher-risk fleets are now diverting to PSMA non-party State ports. Overall, over the same period, port State risk globally has improved only marginally (by 0.52%). Hence, rather than a gradual improvement of the global port risk situation, this paper detects a shift of higher risk fleets diverting their business to higher risk port States.

Quality of governance is a stronger predictor of port State performance than national income. While a weak but significant global trend shows that port State measures generally strengthen with rising national income, this paper verifies that entire world regions may produce a statistically significant opposite correlation, where rising income goes hand-in-hand with weakening port State performance.

[39] *Carding status* refers to the status of the exporting third country under the EU IUU Regulation, which can be yellow (pre-identified), red (identified), or green (not identified / cleared of prior identification).

[40] EC No. 1005/2008, Article 4(1).

[41] EC No. 1224/2009, Article 5(4).

[42] EC No. 1005/2008, Article 38.

[43] EC No. 1005/2008, Article 31(3).

[44] Although the inclusion of an indicator scoring the implementation of the designated port entry rule had been envisaged in the early design stages of the methodology for the 2019 study, neither that study, nor this updated paper could integrate the indicator into the port State risk score, because not enough countries had ratified the PSMA, nor had enough countries fully designated their ports. Applying such indicator in the absence of these pre-conditions risks to skew/falsify results.

Data Availability

Data will be made available on request.

Acknowledgments

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Conflict of interest

The authors declare not to have any financial interest in this work, nor any conflicts of interest relating to this work and its substantive findings.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.105751.

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