

ENVIRONMENTAL STUDIES

Fish crimes in the global oceans

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This study provides a global assessment of the linkages between observed fisheries-related offenses across the world's oceans between 2000 and 2020. We analyze data from the largest existing repository with 6853 events reporting offenses across 18 fishing-related categories, including illegal fishing, human rights abuses, and smuggling. We find that at least 33% of all recorded offenses are associated with 450 industrial vessels and 20 companies originating from China, the EU, and tax haven jurisdictions. We observe links between various types of offenses for 779 vessels, with such "transversal criminality" involving 2000 offenses and crimes globally. This study demonstrates the ability to identify offenders and patterns of behaviors threatening fisheries sustainability at a global level and countries most vulnerable to transversal criminality. In light of concerns for widespread underreporting and impunity, we call for greater information sharing, interagency cooperation, and stringent enforcement to bring to account major offenders.

INTRODUCTION

Illegal fishing is ubiquitous across the world (1), threatening fisheries sustainability and inflicting high costs on the environment and society through declines in fish population, ecosystem degradation, revenue losses, and food insecurity (2, 3). Motivated by high demand for seafood, profit-seeking, and fewer fishes (4), illegal fishing accounts for nearly 11 to 26 million tonnes representing a quarter of the US\$120 billion global landed value of fisheries (1, 5). As a transnational and organized activity (6, 7), illegal fishing potentially lends itself to labor and human rights abuses, as well as the trafficking of drugs, migrants, weapons, and wildlife (8), particularly in poorly regulated spaces (4, 9). This paper is the first global analysis connecting multiple types of offenses across the fishing industry in the world's oceans, using a sample of 6853 reported offenses linked to fishing vessels and fishing companies across 18 different offense subcategories falling within three main categories ("fishing offenses," "fraud and diversion offenses," and "other personal and property offenses"; see Table 1).

International attention over maritime offenses have sharply increased over the past 15 years as a result of growing evidence of the role of illegal fishing in collapsing fish populations (10), mobilization against piracy off the coast of Somalia (11), and greater exposure of slavery at sea (12). Resolutions by the United Nations (UN) General Assembly and the UN Security Council, as well as reports by the Interpol Fisheries Crime Working Group, the UN Office on Drugs and Crime (UNODC), and research institutions (3, 13), have pointed at transversal criminality issues relating to the fishing sector, the concept of transversality embodying the implicit behavior through which different categories of crimes co-occur in a single event, including fisheries offenses, human rights abuses, and various forms of trafficking and fraudulent practices enabling illegal fishing. These practices include document forgery, money laundering (14), forced labor, tax fraud, and the use of flags of convenience and tax and regulatory havens (15, 16). Operationally, vessels evade detection and reporting of illegal activities through failing to declare their presence and activities; turning off vessel monitoring systems, radars, and

lights; transshipping catch and provisioning at sea; catch misreporting; and fish mislabeling (17, 18). Evasion also frequently includes threats and abuses against official fisheries observers, even cases of murders at sea, with observers lacking adequate protection measures and with abuses being frequently underreported by their own agencies for the sake of protecting vested interests associated with illegal fishing (19). Even when offenses are detected and denounced by mandated agencies, vessel apprehension and accountability are often undermined by bribing and pressure on local authorities, complex corporate ownership networks, multiple jurisdictional layers between vessels and companies, and the acquisition of asset nominees, along with common changes in vessel color, name, and flag state jeopardizing the identification of beneficial owners (16, 20, 21). When enforcement becomes more effective, vessels tend to shift their operations to alternative areas or seek to flaunt regulations, for example, through flagging their vessel and re-registering it or the company as a "domestic" venture rather than a foreign one to maintain access to domestic waters (22) or reflagging to a state with lax regulations (23).

Criminality research has focused in the past decade on the concept of crime linkages in investigative contexts of crimes such as sexual assault, burglary, and others, illustrating that accurate crime linkages can help enforcement and surveillance agencies allocate the proper resources to monitor a sector, deter crime, and save lives (24). Understanding and documenting the likelihood of co-occurrence of crimes can lead to a better conceptualization of temporal, geographic, and behavioral patterns that can lead to better detection and deterrence of crimes. The concept of transversal criminality has broader policy and practical implications on other sectors. For example, similar behavioral analysis could be used to underpin situations in which illegal logging is linked to corruption and fraud, which are prevalent in some geographic contexts (25–27). In the mining sector, the concept of transversal criminality, and its drivers such as profit generation and reduction of costs, can lead to a better understanding of the link between child labor, illegal mining, and pollution (28).

International concerns over offenses related to fisheries have increased over the past two decades to a point that the U.S. Coast Guard called illegal fishing "a threat to national security" (29), with multinational efforts seeking to curb down illegal fishing, piracy, and drug trafficking. Many of these offenses have transnational and cross-sectoral dimensions (30, 31). However, regulatory efforts targeting illegal fishing still mostly seek to detect and prosecute fisheries

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Table 1. Categories of fisheries-related offenses covered in this study.		
Fishing offenses	Fraud and diversion offenses	Other personal and property offenses
Unauthorized (fishing without a permit or a license)	Interference with the duty of fishery officials (e.g., bribes and threats)	Human rights and labor abuse (e.g., slavery at sea)
Other fishing offenses include the following:	Embezzlement	Smuggling (e.g., trafficking of arms, people, drugs, and other illicit goods)
Gear (e.g., use of prohibited gear, such as drift nets)	Illegal or fraudulent use of flags/registration of home jurisdiction	Violent attack (e.g., physical assaults against other boats and crew, including enforcement agencies and observers)
Noncompliance (e.g., infringement of observer regulations, other regulations)	Forgery/fraud	Waste dumping
Quota related	Name or identity masking	
Species and bycatch related		
Transshipment		
Zone/season	Reporting related	
Unspecified fishing offense (not categorized by the source)		

management offenses through vessel monitoring, control, and surveillance (MCS) and often disregard other types of offenses committed onboard fishing vessels or by fishing companies that are criminal and should be prosecuted as such (7, 9, 32). In parallel, growing human and drug trafficking interdiction efforts on land and through airports have incentivized criminal logistics networks to turn to the maritime sector, including fishing, as a risk-reducing approach to carry out illicit activities (33, 34), with some small-scale fishers being enrolled in illicit drug trade or their boats being bought, stolen, or hijacked by drug smuggling cartels (7, 35).

Few studies have so far systematically conceptualized or empirically verified these links. Some studies have categorized offenses (36–38) and investigated their connections through individual or regional case studies (39, 40). A detailed analysis of illegal fishing vessels caught in Indonesian waters concluded that “Illegal Unregulated and Unreported (IUU) fishing provides the ideal (illegal) environment for fisheries crimes and other forms of transnational organized crimes to flourish” and noted that other offenses include “document forgery; forced labor and abuse; and fisheries violations,” all contributing to the “inner workings of the illegal fishing industry” (41). However, there is no global and systematic identification and estimation of connections between different types of offenses per vessel and fishing company. Previous studies have used the Combined IUU Vessel List (*n* = 312 vessels) (16) and the Criminal Record of Fishing Vessels (CRFV) (15) to analyze various diversion strategies used by

fishing vessels to escape detection by looking into the use of tax havens and flags of convenience, among other strategies. However, analyses of co-occurrences of various types of offenses (i.e., cocriminality or transversal criminality) in the fishing sector remain largely speculative and based on anecdotal evidence [e.g., (7)]. Such lack of combined conceptual clarity and evidence has, in turn, undermined the relevance and effectiveness of policy responses, with interventions more likely to be sector-focused and one-dimensional, and could result in the criminalization of the more visible closer-to-shore sector, that is, the artisanal sector, or the criminalization of the crews who may have been exposed to forced labor and human trafficking (42).

This study constitutes the first attempt at addressing this research gap at a global level and drawing some inferences in terms of policy recommendations and further research needs. Our study uses the CRFV, which is global in scope and draws from multiple types of sources (see Table 4 and table S5). The CRFV data, however, cannot be assumed to be fully representative of the universe of offenses committed but not detected and reported. Numerous jurisdictions still lack adequate MCS, and even when fisheries observers or other agencies identify offenses, many are not publicly reported and acted upon (see Discussion). Hence, our results provide a first and limited assessment of trends, patterns, and determinants of the co-occurrence of fisheries-related offenses and major offenders in the world’s oceans.

RESULTS

We base our analysis on the CRFV database record of observed, interdicted, or absconded events (“incidents”), each of which includes one or several associated fraudulent or illegal activity (“offenses”), which took place between 2000 and June 2020 inclusive (thereafter “2020”). Incidents (*n* = 6853) and associated offenses (*n* = 7962) involving known fishing vessels (*n* = 2034), unknown fishing vessels (4019), and fishing companies/individuals not overlapping with the previous vessels (*n* = 1050) were compiled from four main sources: government reports (19%; e.g., Coast Guards and fishery observers), third-party reports (75%) (e.g., Greenpeace and media), automatic identification system (AIS) track overlap analysis (5%) (e.g., Global Fishing Watch), and confidential informants (0.3%; e.g., MCS staff in various countries; see Methods). Reports were identified in eight languages (Arabic, Chinese, English, French, Spanish, Indonesian, Italian, and Portuguese) to reduce an English-bias effect. We emphasize the limitations affecting the identification, reporting, and prosecuting of offenses, such as a lack of MCS capacity, confidentiality rules about disclosure (e.g., public reporting only after successful prosecution), and subjective decisions on the part of enforcement agencies including as a result of threats (e.g., against fisheries observers), conflicts of interests (e.g., shareholding in company by local officials), or outright bribery. There can be great diversity of reporting level within a government or even specific institutions. For example, in the United States, some National Oceanic and Atmospheric Administration programs turn everything over to enforcement, while others make a judgment call at debriefing, with company information being often kept confidential, except when cases are finally (though rarely) successfully prosecuted. This study thus provides a preliminary and partial assessment, as the CRFV database is not a random sample but a repository of empirically verified account of existing and accessible records at the global level. We tested the correlation between the level of reporting and the occurrence and origin of intensity of offenses lumped together and found no

correlation (see table S6), which further highlights that the presence of observers does not necessarily increase crime detection. We conducted a regression analysis to see if individual categories acted differently and affected underreporting practices and found significant correlations between underreporting and fraud/forgery and fishing-related offenses (IUU) (see table S7), indicating a link between low ability to monitor catches with fraud and forgery and fisheries violations. This can be explained by the fact that fisheries observers and their agencies, with the exception of those that fall under regional fisheries management organization (RFMO) jurisdiction for particular fisheries, do not often report maritime crimes and illegal fishing because of constraints such as a restriction of their role to scientific fisheries monitoring, threats of violence by the fishing crew or the company, and, in some cases, bribery or pressures from the industry and high-level officials (18, 19, 43).

Fisheries-related offenses in time and space

The CRFV covers the period between 2000 and 2020, but reporting rates are expected to have increased over that period, partly because of more accessible data from government and greater media interest. While the rising trend of reported incidents over the 2010–2019 period (Fig. 1) is likely exaggerated by increasing reporting, reports (9) indicate an increasing trend in illegal fishing within particular regions such as West Africa and increasing drug trade globally within the fishing sector (35). The geographic distribution of all fisheries-related offenses recorded in the CRFV for the 2000–2020 period, assuming that coverage was similar geographically, shows a wide distribution globally (Fig. 2), with hot spots in East Asia (especially Japan, China, and South Korea) accounting for 41% of all reported incidents, West Africa with 16% of all incidents, and Southeast Asia with 8% of all incidents, with still extensive reporting of incidents in Western Europe (5%). Considering only the industrial sector, West Africa is reported to be a major hot spot for illegal fishing and associated crimes with 27% of all incidents, followed by countries from Southeast Asia (8%) and those of Western Europe (7%). Removing incidents reported through AIS track analysis, which mainly covered West and East Africa, reduces the West Africa share of worldwide offenses linked to the industrial sector to 6%, suggesting that at least 21% of potential offenses for the industrial sector are not resulting from government or other reporting.

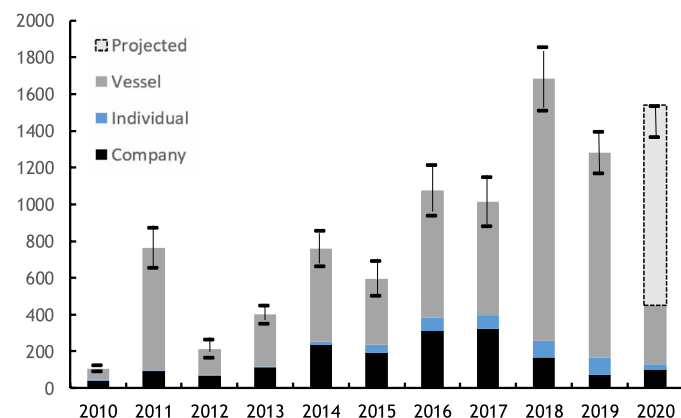


Fig. 1. Total number of incidents reporting fisheries-related offenses as extracted from the CRFV, 2010–2020. Confidence intervals are shown in the graphic and are calculated on the basis of the source of the information.

Analysis of offenses types and fishing sectors

Our analysis reveals that the most common offense remains fishing without a license or permit, with 48% of all offenses, and other fishing offenses (31%) including gear, season- and zone-related, under-reporting, and quota-related offenses, followed by human rights and labor abuse (11%); transshipment (3%); and smuggling of drugs, arms, and other goods and products (4%). Among offenses for which the sector was disclosed ($n = 7166$ or 90% of all offenses and $n = 5482$ or 80% of all incidents), the artisanal sector ranks first in terms of occurrence with 56% of offenses, followed by the industrial sector with 44% (Fig. 3). The industrial sector, however, ranks first in terms of diversity of co-committed offenses (i.e., diversity of nodes) and is dominated by unauthorized fishing offenses (30%) and other fishing offenses (39%), followed by human rights and labor abuse (13%), fish transshipment offenses (8%), forgery and fraud (4%), and smuggling (3%), among other offenses (Fig. 4). The industrial sector also accounted for 91% ($n = 789$) of the 1300 non-fishing-related offenses identified by sector. Over 90% of all offenses in the artisanal sector are for unauthorized fishing (Fig. 5), dominated notably (74%) by a high number of North Korean small-scale vessel incursions into the Sea of Japan and small-scale Vietnamese vessels into various countries' exclusive economic zones (EEZs) in South East Asia. Smuggling, forgery, and fraud constitute less than 3% of all offenses in the artisanal sector.

The influence of fisheries types, by species or by gear, could only be assessed for 1472 of 6853 incidents. Of those incidents, demersal and shrimp trawlers account for 40% of all counts, followed by tuna vessels with 35% of all counts, reefers with 15%, small pelagic fishing vessels with 6%, and cephalopod trawlers and squid jiggers with 4%. These results are clearly biased toward demersal trawlers, whose illegal activities often occur within the continental shelf area of coastal countries and are hence closer to shore and easier to be caught fishing illegally. Demersal trawlers are more likely to fish within prohibited zones (i.e., those areas close to shore where demersal species are mostly found), with 21% of all offense types and 22% unauthorized fishing. Reported offenses relating to the catch and level of fishing effort are mostly occurring (70%) within demersal fisheries (Fig. 3).

Tuna vessels, often active much further from shore and therefore more difficult to observe, are more likely to fish without an authorization (with 25% of all their offenses being unauthorized fishing) and more likely to engage in human rights and labor abuse, with 16% of all their offenses, which corroborate disputed findings from (42), but see (43). Human rights and labor abuse by tuna vessels constitute 42% of all human rights and labor abuse instances captured by the database. Most (95%) of the information comes from third-party reports, and the rest comes from government reports. Tuna vessels are also the most likely to engage in illegal reflagging, as they alone take on 75% of all illegal reflagging activities, commit fraud with 42% of all fraud-related offenses, and catch prohibited species with 73% of all species and bycatch-related offenses (many of which have to do with shark finning, as a major by-activity of tuna fisheries, globally).

Transversal criminality analysis

Of the 6853 incidents recorded, 6003 incidents (88%) involved fishing vessels caught for a single type of offense: 4954 for one illegal fishing; 523 for human rights or labor abuse; 309 for smuggling of illicit drugs, arms, or other products; 140 for illegal transshipment; 66 for illegal diversion including noncompliance strategies, forgery, or the illegal use of flags; 12 for violent attacks; and 5 for waste

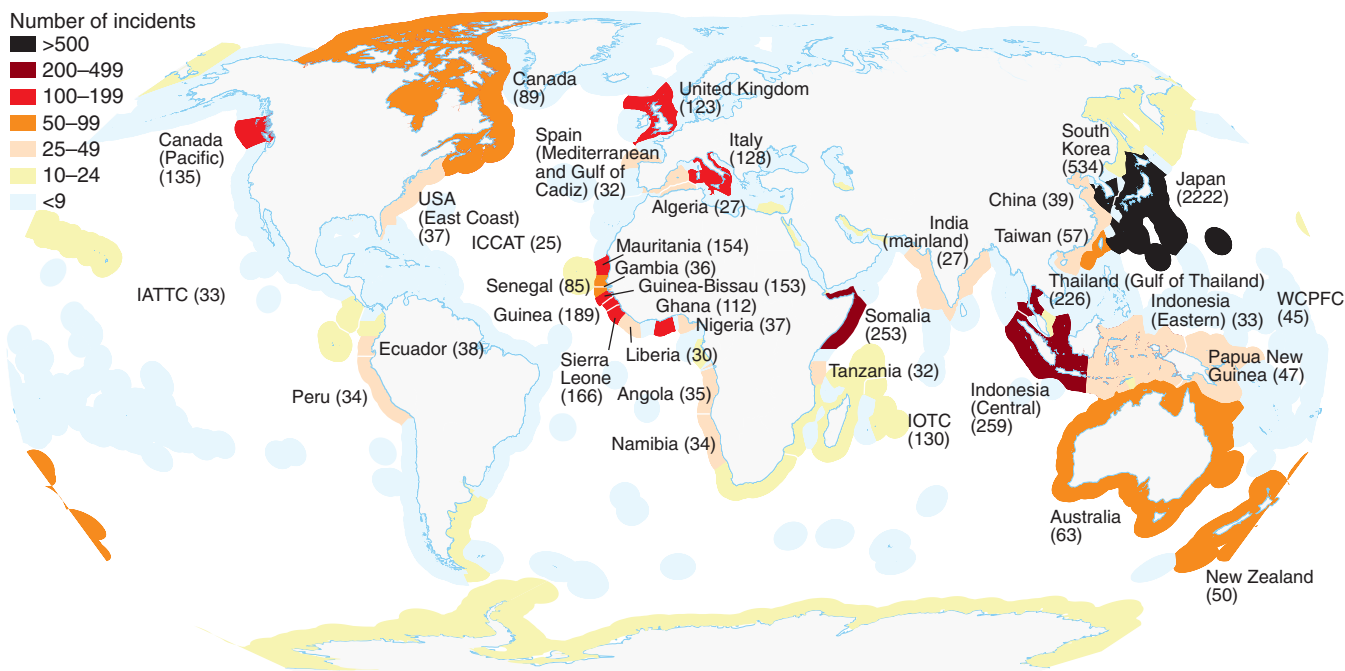


Fig. 2. Hotspots of reported fisheries-related offenses in the world between 2000 and 2020. Data are extracted from the CRFV, using exclusive economic zone (EEZ) boundaries. Offenses from the U.S. Pacific Coast and Mexico, Northern Russia, and Myanmar were not accessed at the time of this study because of time constraints or language barriers. WCPFC, Western and Central Pacific Fisheries Commission; IOTC, Indian Ocean Tuna Commission; ICCAT, International Commission for the Conservation of Atlantic Tunas; IATTC, Inter-American Tropical Tuna Commission.

dumping. The remaining 772 cases of incidents (11%) included at least two types of offenses. Nodes identified from incident reports involved different types of illegal fishing categories (36% of all existing nodes), co-occurrences of illegal fishing, and human rights abuses (38% of all existing nodes) or labor abuses (4% of all existing nodes). This supports the literature finding strong links between illegal fishing and human rights and labor abuse (44). Illegal fishing is linked to other non-fishing-related offenses in 57% of the cases with two or more offenses. Illegal fishing events occur concurrently with nonfishing types of offenses in 12% of incidents involving industrial fishing vessels, compared to 2% for artisanal vessels.

Interactions with labor abuses and slavery at sea

Human rights abuses consist of the nonobservance of human rights, as established through the UN Charter and the Universal Declaration of Human Rights. Forced labor is recognized as a type of modern slavery, embedded within a current human rights crisis. According to the International Labor Organization, forced labor consists of “all work or service which is exacted from any person under the menace of any penalty and for which the said person has not offered himself voluntarily” (45). Labor abuses relate to abuses concerning labor rights and regulations and include all forms of violence, penalty, excessive overtime, threats, confiscation of documents, sequestration, and other forms of abuse such as unsafe work conditions. Human rights abuses are linked to some IUU activities through the drive to maximize profit and minimize costs. Several studies have linked illegal fishing to labor abuses including slavery (40, 41, 46). The hypothesis is that illegal fishing occurs to maximize benefits, and slavery or slave labor is often driven by the incentive of lowering costs in countries where the monitoring of these activities is often limited. Our analysis shows that these cases are notably reported

for slavery aboard occurring in the territorial waters and EEZ of Bangladesh, Indonesia, Malaysia, Papua New Guinea, Somalia, South Africa, and Thailand with over 291 cases globally where illegal fishing was linked to forced labor. All of these cases occurred on industrial vessels and by their crewing companies involving either companies or individual recruiters.

Interactions with smuggling (drug trafficking, weapons trade, and other goods)

UNODC have linked illegal fishing to smuggling (7), including drug trafficking (35, 47). Our analysis points to 12 co-occurrences, with three main hot spots for drug smuggling, as 23% of all smuggling-related offenses occurred in Latin America and the Caribbean (west of FAO area 31), 23% in the Mediterranean Sea [Food and Agriculture Organization of the United Nations (FAO) area 37], and 15% in the Arabian Sea and Western Indian Ocean (FAO area 51). We note that co-occurrences could be low, as fishers may get involved in both illegal fishing and smuggling but not simultaneously (e.g., some Iranian dhows deliver illicit drugs in East Africa and fish illegally on their way back), MCS may lack the capacity to tackle two different types of offenses (e.g., narcotics detection), narcotrafficking organizations may use or recruit “clean vessels” not involved in fisheries-related offenses to avoid suspicion, and fishers trafficking drugs may not illegally fish or avoid it to reduce the risk of getting caught (35). Over 60% of all smuggling offenses were by the artisanal sector, 23% by the industrial sector, and the sector for the remaining cases could not be identified.

Interactions with piracy and violent attacks

Illegal fishing has been linked with piracy but generally in the sense of piracy being the result of illegal fishing (48, 49) and possibly reducing illegal (but also legal) fishing through deterrence (50)

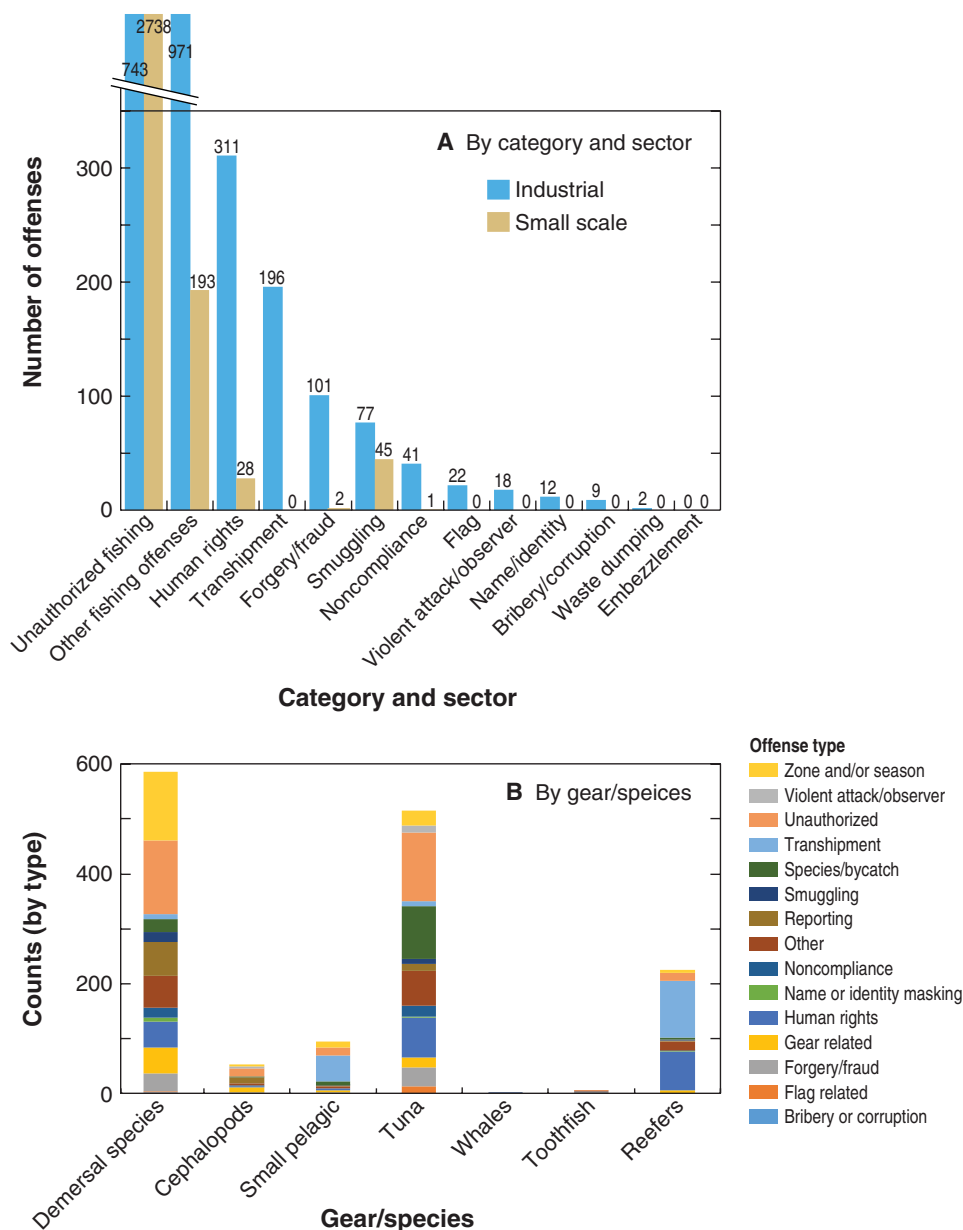


Fig. 3. Contribution to fisheries-related offenses by category and sector (top) and by gear/species (bottom), 2000–2020. Data extracted from the CRFV. This figure gathers all unauthorized fishing offenses into one category labeled “other illegal fishing,” which are often considered a matter of regulation and not a crime, such as fishing with a prohibited gear (see Table 1). All offenses associated with a high uncertainty score of 3 to 4 were removed from gear analysis, as their gear type was not known or documented (see Methods).

rather than illegal fishing vessels also getting involved in piracy and robbery at sea (including vessel hijacking, kidnapping of crew, and theft). There is some evidence of opportunistic piracy undertaken by illegal fishing vessels operated by “polycriminal” entrepreneurs (51), especially as vessels involved in both fishing and piracy extend their range and operate in foreign EEZs without authorization (52). Violent attacks besides piracy are more widely documented and take on different forms (53), including attacks to drive out competing fishing vessels (54) and attacks on enforcement organizations including threats and suspicious disappearances and deaths of fisheries

observers (55). Our analysis of attacks involving at least two vessels (one attacker and one attacked) are mostly found off the coast of East Africa (FAO area 51; 25%), the Gulf of Guinea (FAO area 34; 25%), East and South East Asia (FAO area 71; 25%), South Mediterranean (17%), and Western Europe (8%; FAO area 37). The majority of violent attacks occurred by industrial vessels (83%).

Observer threats, harassment, interference, and assault

Also part of violent attacks is an ill reported category (56). Assault is defined by the International Observer Bill of Rights (IOBR) as any physical or verbal attack and any form of threat to do bodily harm

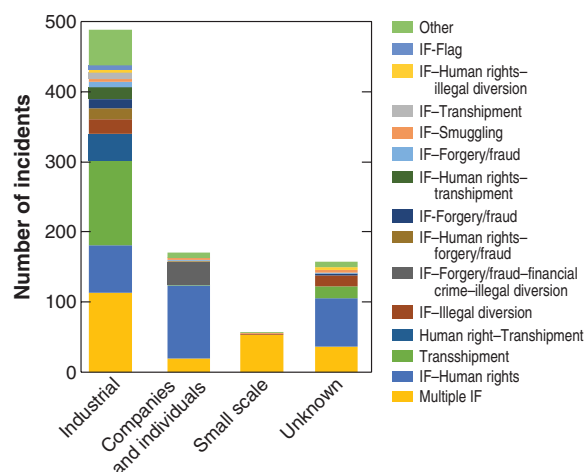


Fig. 4. Number and typology of offense node combinations by fishing sector.

The category “unknown” documents vessels for which the sector could not be determined. IF refers to “illegal fishing offenses” and includes unauthorized fishing and other fishing offenses as shown in Table 1. Data extracted from the CRFV for 2000–2020. Company and individual offenses represent only those companies or individual for which offenses are not linked to vessels listed through, e.g., ownership.

or sexual violence (rape) or attempt to destroy personal or professional property of the observer. The IOBR defines harassment as all activities (including verbal communication) that “creates an intimidating, hostile, or offensive environment, with or without the intention of interfering with the observer’s duties.” This also includes sexual harassment as defined in (57) and more subtle forms of harassment. Interfering with observer’s duties includes all physical or nonphysical manipulation that affects the ability of the observer to conduct their duties. We note that this category is difficult to quantify given that many, if not most, observer disappearances and deaths have not been investigated properly and are hence often decriminalized with no further actions.

Interactions with pollution and other environmental offenses

Illegal fishing contributes to environmental degradation in the ocean mostly through overfishing and harmful fishing practices, including the use of prohibited gear, as well as “abandoned, lost or otherwise discarded fishing gear” (58). No global study has specifically pointed at the role of illegal fishing in ocean pollution, but considering that illegal fishing accounts for 10% of fishing activities, it could amount to 4.5% of macroplastics at sea (59). The CRFV does not record plastic pollution by fishing vessels, mainly because this form of pollution is not necessarily punishable by law or sanctioned, but waste dumping occurs, including the discharging of oily waste and illegal sewage (six incidents recorded). Two-thirds of the cases were committed by the industrial sector, and the remaining were committed by unknown sectors.

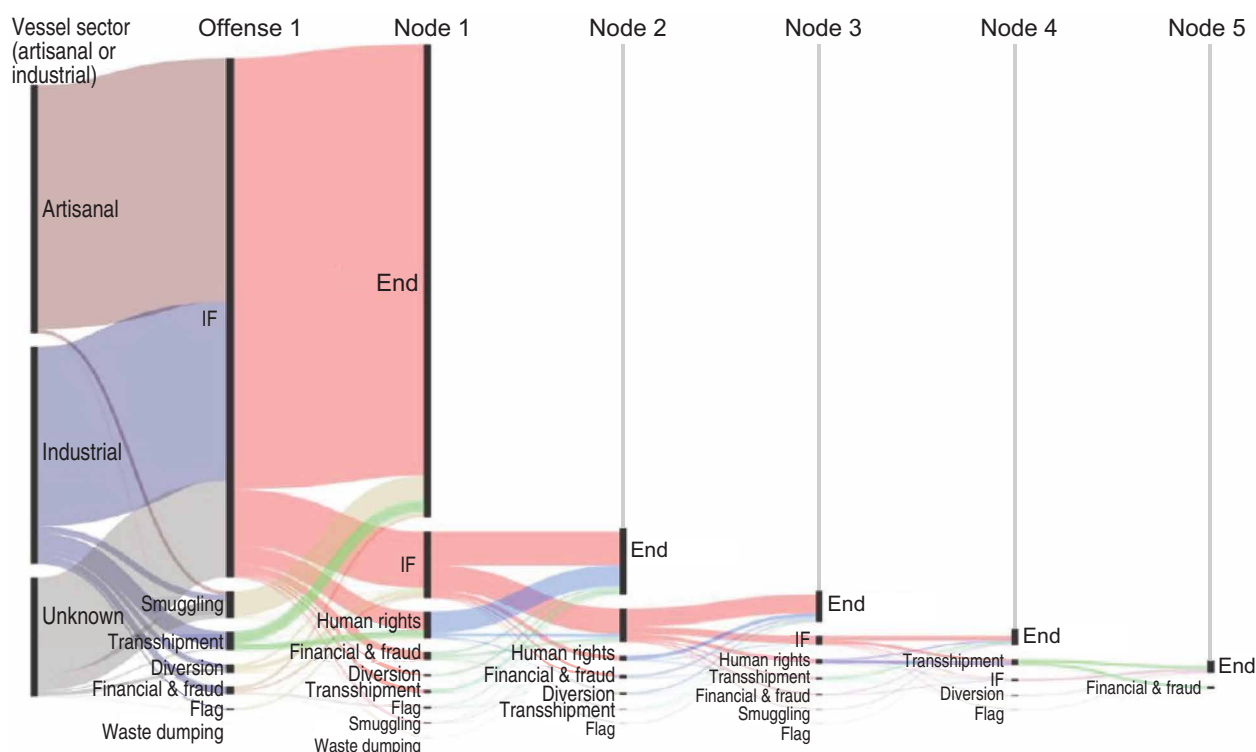


Fig. 5. Typology of fisheries offense nodes in the fishing sector between 2000 and 2020 for fishing vessels. The further a flow goes, the higher the interlinkage score, meaning multiple offenses co-occurred in that single incident. Data were extracted from the CRFV. Each black bar is labeled with the corresponding offense category (except for the first bar from the left relating to the fisheries sectors); the colored flow after each bar documents the category of that bar. The red shades represent illegal fishing labeled IF and unauthorized offenses; green shades represent transshipment offenses, and purple shades represent human rights and labor abuse offenses. If a red shade (IF) is followed by a purple shade (human rights and labor abuse), it means that those two offenses were found in a similar incident.

Human rights and labor abuse offenses score 1.6 in terms of linkages (meaning that vessels reported for these offenses have, on average, 1.6 categories of offenses). Human rights and labor abuse co-occur commonly with transshipment offenses, illegal fishing offenses, and illegal diversion offenses such as violent attacks and noncompliance offenses. Offenses related to vessels trying to evade sanctioning or interception, such as noncompliance, name or identity masking, forgery or fraud, bribery, and corruption, occur only 3% of the time; however, they have a linkage score of 2.2 to 2.4. This is not unexpected given that these types of offenses are committed to evade sanctioning for the occurrence of another offense. Overall, nearly half of the vessels caught with an offense of human rights and labor abuse have committed another offense, typically illegal fishing (86% of the links) and transshipment (16% of the links), and are also linked to forgery, fraud, smuggling of goods and products, and waste dumping.

Only 12% of the vessels listed on CRFV with illegal fishing offenses have links to other offenses, and 39% of these links are to other fisheries-related illegal fishing offenses, 34% to human rights and labor abuse, and 4% to transshipment offenses. Over 97% of smuggling offenses are not linked to any other reported offense, which confirms the conclusions reached by Belhabib *et al.* (35). Transshipment offenses are linked to other offenses in 42% of the cases. Transshipment offenses commonly involve reefer vessels; hence, in 65% of the cases, they do not co-occur with other illegal fishing-related offenses. However, we find here that in 25% of the cases, illegal transshipment is linked to human rights and labor abuse offenses, including through keeping workers longer at sea and preventing them from escaping poor working conditions and/or filing complaints when reaching nearshore or harbors (60–63). Nearly 20% of transshipment offenses were linked to illegal fishing offenses, by accepting or transshipping illegally caught fish. In 7% of the cases, transshipment offenses occur alongside both illegal fishing and human rights or labor abuses at sea.

Risk factors associated with transversal criminality

Having identified the co-occurrence of different types of offenses, we performed a statistical analysis to determine the influence of country characteristics on transversal criminality. The regression model predicts node occurrences, with an adjusted R^2 of 0.85. Government effectiveness is correlated negatively with offense intensity (i.e., the number of times cocriminality occurred), reducing offense intensity by 0.1% per unit ($P = 4.739 \times 10^{-5}$). The higher the corruption and the unemployment rate, the higher the intensity of offenses. Offense intensity within a given EEZ is positively correlated with unemployment and corruption and negatively correlated with government effectiveness. Overall, the model indicates that some types of offenses are more likely to be associated with an increase in criminal behavior. For example, an increase in one unit of bribery/corruption results in a 1.6 increase in average offense intensity, something generally explained by the frequent use of bribes to facilitate criminal practices when there are sanctions, although we note that the offense intensity is probably much higher since nonreported bribe payments are likely to hide nonreported offenses (see Table 4). Hence, corruption seems to have a multiplier effect, whereby it either enables or motivates more offenses to be committed (e.g., expectation of only having to pay a relatively small bribe for an offense induces captains and companies to increase still profitable offenses). This multiplier effect implies that the presence of a given type of offense is likely to indicate the occurrence of, or even generate, another type of offense.

Overall, variables with the highest impacts on the co-occurrence of offenses (cocriminality) are bribery/corruption, illegal use of flags, illegal fishing offenses, waste dumping, and illegal transshipment (see Table 2).

Reported illegal fishing offenses occur throughout the wide enforcement-level spectrum of EEZs but are most common in countries with a high control of corruption and high government effectiveness rate (fig. S2), notably in Canada and Japan where MCS is well developed, particularly for coastal fisheries. Diversion, including attempted bribery, corruption, and noncompliance, seems to occur in environments where the control of corruption is low (e.g., Indonesia, Somalia, Sierra Leone, and Guinea) (fig. S2), regardless of the government effectiveness, exposing how vessels and companies profit of high prevalence of corruption to escape sanctioning. Transshipment offenses tend to occur in countries where government regulatory effectiveness is limited, pointing to factors such as lack of monitoring, lack of political will, or the lack of a proper regulatory framework with regards to transshipment.

We also conducted a regression analysis to test for the spotlight effect and the effect of the freedom of the press on reporting offenses. We found that while the model explained less than 1% of the variation, the Press Freedom Index may be positively correlated with the intensity of offenses (see table S8).

Major offenders

Our final analysis seeks to identify companies associated with numerous offenses. This analysis is limited, as only 1700 of 6853 incidents identify a company associated with the incriminated fishing vessels. Many governments keep company names confidential. Hence, we used an investigative approach to link the vessels to their beneficial owners. First, we searched the names of the vessels with at least the International Maritime Organization number, the Maritime Mobile Service Identity (MMSI), or the call sign in public databases listing the front owner of the vessel. Whenever the front owner is based in the coastal state yet there is an indication that the vessel is foreign owned, we deepened the search by investigating the front owner and the potential links to other companies by reviewing registration records found in public corporate registers, company websites, and financial reports, allowing us to identify beneficial owners. Within that sample, a third of all illegal activities ($n = 684$) were linked to 20 companies (Table 3), noting that the reported company name may not be the ultimate beneficiary owner and further concentration among key offenders is possible. At first glance, it appears that 50% of all companies listed in the criminal record are based in China (20% of the total counts of offenses), the European Union (EU) (13%), and Canada (10%), followed by tax haven countries (9%) that are often used to shelter financial transactions and hide illicit activities (fig. S3) (15, 16). Companies based in Ghana (6%), Indonesia (6%), and Thailand (5%) constitute a cumulated 17% of ownership base. These three countries are reputed for sheltering front companies from China, Spain, and other jurisdictions (21, 64, 65). Note that coverage will vary from country to another, which will affect a sector's prevalence in the database. The industrial sector records 44% of their offenses, and 85% of industrial vessels have reported flag registered within a distinct jurisdiction other than that where offenses occurred, with vessels mostly being from China (28%) and the EU (10%). We find here that 3 of the top 20 companies with the highest number of offenses figure among the top 10 companies with the highest fishing effort in the high seas (66).

Table 2. Linear regression results showing correlations between offense intensity, types of offenses, governance, and social indicators of coastal countries. Data were extracted from the criminal record of fishing vessels and World Bank Databases. Coefficients represent the predicted value of the multiplier and, thus, the variable's impact on co-occurrence/cocriminality.

Variable	Coefficients	SE	t stat	P value
Bribery/corruption	1.5909102	0.0581272	27.36945	2.12×10^{-155}
Flag	1.3305784	0.0415406	32.03081	9.45×10^{-208}
Illegal fishing	1.2938773	0.0108365	119.3999	0
Waste dumping	1.2768898	0.0828083	15.419835	1.257×10^{-52}
Transshipment	1.2157453	0.0169745	71.621739	0
Unauthorized	1.196381	0.0110504	108.26632	0
Smuggling	1.1924261	0.0169337	70.417383	0
Human rights	1.1170536	0.0125638	88.910409	0
Violent attack	1.064243	0.067492	15.768421	6.644×10^{-55}
Name/identity	1.0526828	0.0386732	27.219949	8.01×10^{-154}
Noncompliance	0.9943423	0.0297423	33.431905	1.25×10^{-224}
Forgery/fraud	0.9940199	0.0206377	48.165306	0
Embezzlement	0.3077547	0.0706989	4.3530366	1.365×10^{-5}
Control of corruption	0.0018243	0.000303	6.0216184	1.831×10^{-9}
Unemployment	0.0013361	0.0009944	1.3436483	0.1791136
Government effectiveness	-0.001199	0.0002945	-4.071159	4.739×10^{-5}
Intercept	-0.237105	0.0142946	-16.58697	1.969×10^{-60}

DISCUSSION

Working within the confines of CRFV’s 6853 incidents reporting one or several offenses by a fishing vessel across 18 categories of offenses within three main sets (fishing offenses, fraud and diversion offenses, other personal and property offenses), this study found that the vast majority of incidents are related to various types of fisheries offenses (mostly unauthorized fishing), followed by human rights abuses, smuggling, and diverse types of frauds with very few incidents reporting violent attacks.

Sector

Artisanal fishing vessels were ranked first in terms of offense occurrences (47%), but the vast majority of offenses (90%) only related to unauthorized fishing, with other offenses generally related to drug smuggling. The industrial sector accounted for fewer of the database-recorded offenses (39%) but was much more likely to be involved in other types of offenses. Moreover, the scale of impacts of offenses by industrial vessels can be expected to be much higher than for artisanal vessels (see further research below).

Offense

Corruption was the most likely to be associated with criminal behavior (offense intensity of 1.6), putting an emphasis on the need to identify and report vessels and companies bribing officials and, more generally, to curb corruption in the fisheries sector. In contrast, fishing vessels involved in drug trafficking were less likely to commit other offenses, suggesting that suspicion of involvement in smuggling should not rely on the detection of fisheries offenses. Vessels with reported human rights and labor abuses offenses frequently committed other types of offenses, including illegal fishing, transshipment, fraud, smuggling, and waste dumping,

suggesting that these vessels systematically seek to reduce costs through criminal practices and should be targeted for several enforcement measures, including the seizing of vessels given the risk of reoffending.

Location

Illegal fishing offenses were mostly reported in countries with high MCS (such as Canada and Japan). Fraudulent and diversion offenses mostly occurred in countries with weak governance and likely to be more consequential in terms of financial and fish population losses.

Offender

Transversal criminality is mostly occurring within the industrial fishing sector and would most frequently involve Chinese vessels and companies, followed by vessels flagged in the EU, Tax Havens, Indonesia, and Thailand. Among the top 20 perpetrators, 12 were (apparent) Chinese companies, pointing to the need for Chinese authorities to intervene even more stringently and cooperate with jurisdictions in which its fishing fleet is in operation. Other home country governments, not only including Tax Haven countries and countries in East and Southeast Asia but also elsewhere such as Canada, must also rein in the criminal/illegal behavior of some of their companies and fishing vessels. We found evidence suggesting that some front companies, subsidiaries, and concealed ownership networks may hide a high risk of offenses associated with the true beneficial owner of one company (e.g., Fuzhou Hong Long Ocean Fishing, which before beneficial ownership analysis appeared to be scoring only three incidents but, after investigation, could score the highest number of offenses globally with 100 multi-jurisdictional offenses, possible shareholding, subsidiaries, and branches, notably PT. Mutual Dwikarya Abadi). This points to the importance of beneficial ownership analysis when dealing with criminality at sea.

Table 3. List of major companies responsible for a third of reported fisheries-related offenses within the industrial sector. List based on records is available from the CRFV database, 2000–2020. Companies in bold figure are among the top 10 companies globally fishing in the high seas in terms of fishing effort.

Company/individual name	Offenses	% of total offenses*	Vessel flag used	Ownership remarks (Supplementary Materials)
PT. Mutual Dwikarya Abadi†	100	5%	« Indonesia »	Affiliated with Fuzhou Hong Long Ocean Fishing Co. Ltd. (FHLO), a repeat offender. FHLO shares the same owner with Pingtan Marine Enterprise.
Pingtang Marine Enterprise	92	5%	China	
Fuzhou Hongdong Pelagic Fishery Co. Ltd.	87	5%	China	
Fishing & Cargo Services SA	69	4%	Panama	
Sajo Industries Co. Ltd.	64	3%	South Korea	Owned by Sajo Group
Sajo Oyang Corporation	9	<1%	South Korea	
China National Fisheries Corporation	53	3%	China	Owned by China National Agricultural Development Group Co. Ltd.
Dalian Lian Run Pelagic Fishery Co. Ltd.	41	2%	China	
Zhejiang Hairong Oceanic Fisheries Co. Ltd.	38	2%	China	
Ocean Star (Fujian) Pelagic Fishery Co. Ltd.	29	2%	China	
Dalian Bo Yuan Overseas Fisheries Co. Ltd.	14	1%	China	
Huang Jia Yi	11	1%	China	
Dongxinglong Ocean Fishing Co. Ltd.	10	1%	China	
Qingdao Rongchang Ocean Fishing Co. Ltd.	10	1%	China	
Scott Stanley Matthew Steer	10	1%	Canada	
Sierra Fishing Co.	10	1%	Sierra Leone	
Tuna Atlantic Ltda.	10	1%	Colombia	
Delipisca SA	9	<1%	Ecuador	
Fujian Pingtan Hengli Fishery Co. Ltd.	9	<1%	China	
Rong Cheng Marine Fisheries Co. Ltd.	9	<1%	China	

*For which offenses were documented. †Evidence suggests this company is a subsidiary of a Chinese owned company; see www.sec.gov/Archives/edgar/data/1517130/000114420414047364/R26.htm.

Science and technology

This study reveals how different types of offenses converge and how fishing vessels involved in crime at sea use opportunistic behavior to engage in transversal criminality. Hence, this database and associated reporting mechanisms and analytical processes should be further developed to improve the identification of reporting gaps, their causes, and potential solutions; to combine methods to detect and cross-check offenses and offending companies and beneficial owners; and to facilitate information flows and accountability within

and across jurisdictions. The types of affinities found in this analysis could be used to enhance existing artificial intelligence systems and algorithms that are meant to detect and predict the occurrence of offenses that are difficult to observe, including illegal fishing in areas without strong MCS and/or with high human rights and labor abuses.

Eight policy implications arise from this study, although we note that these recommendations should be read in light of the limits of our study, including partial geographical and sectoral coverage (see Methods). First, fisheries-related offenses should be addressed in relation to a

broader set of criminal practices rather than as an isolated domain, as also pointed out by recent reports and initiatives by international bodies such as INTERPOL and the High Level Ocean Panel [see Introduction as well as (67)], and practices facilitating offenses, such as corruption and diversion, should be more severely sanctioned to make criminal practices harder to perform and more financially risky.

Second, there should be more systematic collection, sharing, and analysis of offenses among agencies and jurisdictions while preventing intelligence leaks that could facilitate offenses. Current data collection efforts are notably coordinated by INTERPOL (“Purple Notices” providing information on *modi operandi*, procedures, objects, devices, or hiding places used by criminals), RFMOs and similar bodies [e.g., The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)–noncontracting party IUU vessel list], and Spyglass.fish, which is the platform publishing the CRFV. Further progress requires increases in MCS capacities and operations, more comprehensive training on the different types of offenses and their relations, more effective protection of fisheries officials against the various pressures that they face in reporting and enforcing regulations, and cross-agency work including the tracking of multiple offenses and flagging of repeat offenders. This, in turn, can help with using proxies to detect co-occurrence of offenses, notably human rights and labor abuses, as well as threats or bribery of fisheries officials, that can point to a higher likelihood of illegal fishing and transshipment offenses.

Third, some activities could be decriminalized, in particular, in countries with poor surveillance and enforcement capacity so as to help reduce diversion, facilitate monitoring, and help focus on high-impact offenses. This is the case of transshipment: If a government is unwilling or unable to monitor its waters, bans on transshipment without enforcement may act as an incentive to still pursue transshipment but does so more clandestinely than if it was authorized and monitored (for example, transshipment activities in the Guinea Bissau EEZ are more easily monitored, as vessels usually keep their AIS on while transshipping, while vessels transshipping in Senegal and Mauritania hide their activities since it is banned, but the governments of Senegal and Mauritania are not necessarily able to detect and intercept these vessels). In addition, some fisheries rely on transshipment to save fuel costs, while many crew members rely on interactions with motherships to get access to satellite connection and get in touch with their loved ones. The idea here is to identify offenses that are likely to create ghost activities and harm crews and observers by banning them in the absence of effective enforcement.

Fourth, the relative minority of vessels and companies that are currently identified as responsible for a large part of offenses should face deeper consequences, including vessel seizures and jail time for beneficial owners, rather than relatively small fines and sentences only for crew and captains (we stress the notion of crew criminalization, which should be studied in depth). Given the profile of companies involved, this will require either that home countries directly intervene in punishing overseas offenses by their companies or that they at least make it understood that punishment by host countries will not face retribution (68, 69).

Fifth, given the overwhelming dominance of industrial fishing vessels associated with transversal criminality, policy and enforcement efforts should direct more efforts toward industrial vessels rather than artisanal fleets so as to maximize positive effects in terms of broad benefits (from healthy fish populations to public revenue and human rights protection) rather than criminalize artisanal fishers at the risk of pushing them further into illegal practices (e.g., drug

smuggling). A nuanced understanding of the drivers of illegality can help reform biased regulations and enforcement unjustly hurting artisanal fishers (70, 71) and inform approaches deterring illegal fishing through compliance benefits rather than punishing measures hurting artisanal fishers. Sixth, our analysis reveals that 85% of the industrial vessels (1336 vessels), for which a flag was identified at the time of the offense (1562 in total), carried a flag whose state was different from the coastal state where they were operating, suggesting that most of the industrial fleet identified in the database operates under the distant water fishing model.

Seventh, enforcement agencies should be more transparent about offenses and incriminated companies (including threats against observers seeking to report offenses), and the information should be made available to the public along with stronger prosecution to foster greater accountability. In particular, agencies need to more systematically report abuses against observers, share knowledge about the cases and perpetrators involved, provide greater protection for observers, and impose sanctions against perpetrators. Last, further research should seek to gather more cases; include specific categories for bribery, threats, or abuses against fisheries officials; refine estimation techniques to better identify and address uncertainties (especially for areas with likely under-reporting); examine reoffending patterns by vessels and companies; and investigate the relative impact of offenses linked to industrial fishing compared to the artisanal sector.

METHODS

Data sources

In this analysis, we use the CRFV, available on the platform <https://Spyglass.fish>. The CRFV is a global database on fishing vessel–related offenses at sea, encompassing all types of offenses occurring and co-occurring onboard fishing vessels, by individuals and companies, globally. The database is a compilation of various sources as indicated below. Note that many of the infractions were not at the stage of prosecution. The reports are based on interdictions, regardless of the result of the legal outcome. Therefore, the reports represent any instances where enforcement, nongovernmental organizations (NGOs), AIS analysis, witnesses, observers, and others encountered an irregularity or an illegality or when a case (previously confidential) was successfully prosecuted:

- 1) Media and NGO publicly available reports (5251 reports; Table 3) documenting all types of crimes listed in the CRFV (table S2). Media (press) reports are mostly postarrest and indicate the vessel name, the location, and other details. NGO reports commonly form a part of an investigation handed to a government (such as the work on human rights and labor abuses by the Environmental Justice Foundation) or a joint patrol activity report (Greenpeace inspections with government agencies in West Africa).

- 2) Government reports (1365 reports; Table 3) commonly report illegal fishing and associated offenses and drug trafficking. Government reports are based on availability/publication on a government website at the time the data are being treated. This includes press releases by the navy/coast guard, reports by the department in charge of (fisheries) surveillance, and regional/intergovernmental agencies (such as RFMOs). Some government reports have not been taken into account at the time of the analysis and hence represent a source of geographic bias (as discussed below). Reports for the United States, for example, only include those reports covering the distant water fishing fleet and not coastal incidents despite their availability

because of time constraints (e.g., some U.S. reports require reading court documents; these will be added to the database at a later stage). This constitutes a source of bias for the coastal fleet; however, it does not affect the transversal criminality analysis given that they usually operate within one type of crime. Other country reports, such as those for Russia, were not included because of the language barrier.

3) AIS track analysis conducted using Global Fishing Watch data overlapped on prohibited areas (374). The full methods for this source are described in (72). This analysis was only performed around the African continent, includes only one type of offense, which is incursions into artisanal zones, and does not report any other overlapping offense because of the nature of the analysis.

4) Testimonies from witnesses, reports, and communications from informants, including those from the industry (heads of association), former crew members, and observers, who document instances of (illegal) transshipments, attempted bribing, and human rights and labor abuse, or offenses committed by seafood and crewing companies, whenever it is safe for the observers to share this information (outside the scope of RFMO, on a personal communication basis), if they are trained to detect them, subject to the lack of corruption. The number of these testimonies and confidential communications is rather low (21) because of the safety risks posed on the crew or the observers. While Spyglass.fish provides an avenue for reporting confidentially, many of these reports cannot be validated properly because of these safety issues.

Data are collected on a daily basis since 2016, whenever these reports are made available, whether online through media searches or through contacts within government agencies and other sources. The compilation does not assess whether these offenses were later proven in courts and thus simply records their reporting, not their legally demonstrated veracity. Identified sources of bias include the following (also see table S5):

1) Media and MCS reports targeting some flags more than others. For example, Chinese vessels could be more targeted by local media than vessels from other countries and possibly by MCS operations. We do not have evidence of this, however.

2) Media and MCS reports targeting some EEZs more than others. For example, West Africa seems to have a higher concentration of environmental NGOs and media/development agency attention on illegal fishing compared to other regions. More quantitative analysis addressing targeted Official Development Assistance (ODA) and targeted grant funding is needed to verify this assumption.

3) Spotlight effect in drug trafficking cases where only major cases (“big busts”) are reported.

4) Despite being easier to monitor because of their proximity to the coast and frequent return to nearby ports and landing sites, the small-scale sector’s monitoring results are not often reported, and sometimes, the sector is not at all monitored. Hence, countries with a high level of monitoring on the small-scale sector and public reporting of associated offenses will tend to show, in relative terms, a positive reporting bias compared to countries with lower level of monitoring and/or reporting but similar level of offenses (e.g., Canada has a high ratio of detected and reported offenses to total offenses committed in the case of these two sectors). This also raises the question of the threshold level for reporting and lack of scale of the offense committed. One single “small-scale” fishing offense may not appear to have the same impact as a large industrial trawler committing a major fishing offense. However, this remains debatable on some levels. For example, one small-scale offense may be only

caught once, but since the sector is not well monitored, it usually hides a much higher level of illegality, including illegal fishing, license fraud, and smuggling of products. Illegality within the small-scale sector can also generate conflicts between, e.g., indigenous or local community members and nonlocal users.

5) Different sources and enforcement agencies will focus on different offenses and report them as such. This suggests that prioritization and deployment for a given purpose will affect the type of illegality encountered and hence reported (if reported). For instance, the U.S. Navy may board a vessel to check for narcotrafficking and may not necessarily check for illegal fishing. The whole idea of transversal criminality, and the lack of links between different offenses therein, suggests that surveillance operations may be typically mono-offense targeted and hence result in this form of bias.

Uncertainty related to information source types

The CRFV relies on three main sources of information, namely:

1) Media reports and government press releases, which are considered as reliable (based on reputation and media accountability) and include mainly observed offenses, regardless of their sanction status. These constitute 76% of the information sources in the database and are associated with a low degree of uncertainty.

Table 4. Sources, uncertainty scores, and number of reported incidents. 1 denotes a higher certainty, and 4 denotes a lower one, with score based on the assessment of confidence level associated with credibility of the source, methodology used, and public disclosure. Note that there are variations within each category due to coverage variability (e.g., some governments may issue information with low certainty score, given the lack of coverage).

Sources of information	Uncertainty score (1 to 4)	Number
Government reports (e.g., Coast Guard, Ministry of Fisheries, RFMO fisheries observer reports, and secondary sources reporting arrests)	1	1365
Third-party reports (e.g., C4ADS, Greenpeace, Environmental Justice Foundation (EJF), and media reporting)	2	5251
Confidential communications (e.g., personal verbal communication from industry sources and government officials, including personal communications from observers)	3	21
AIS track overlap analysis (Global Fishing Watch)*	4	374

*AIS tracks were overlapped with prohibited areas and verified against license lists.

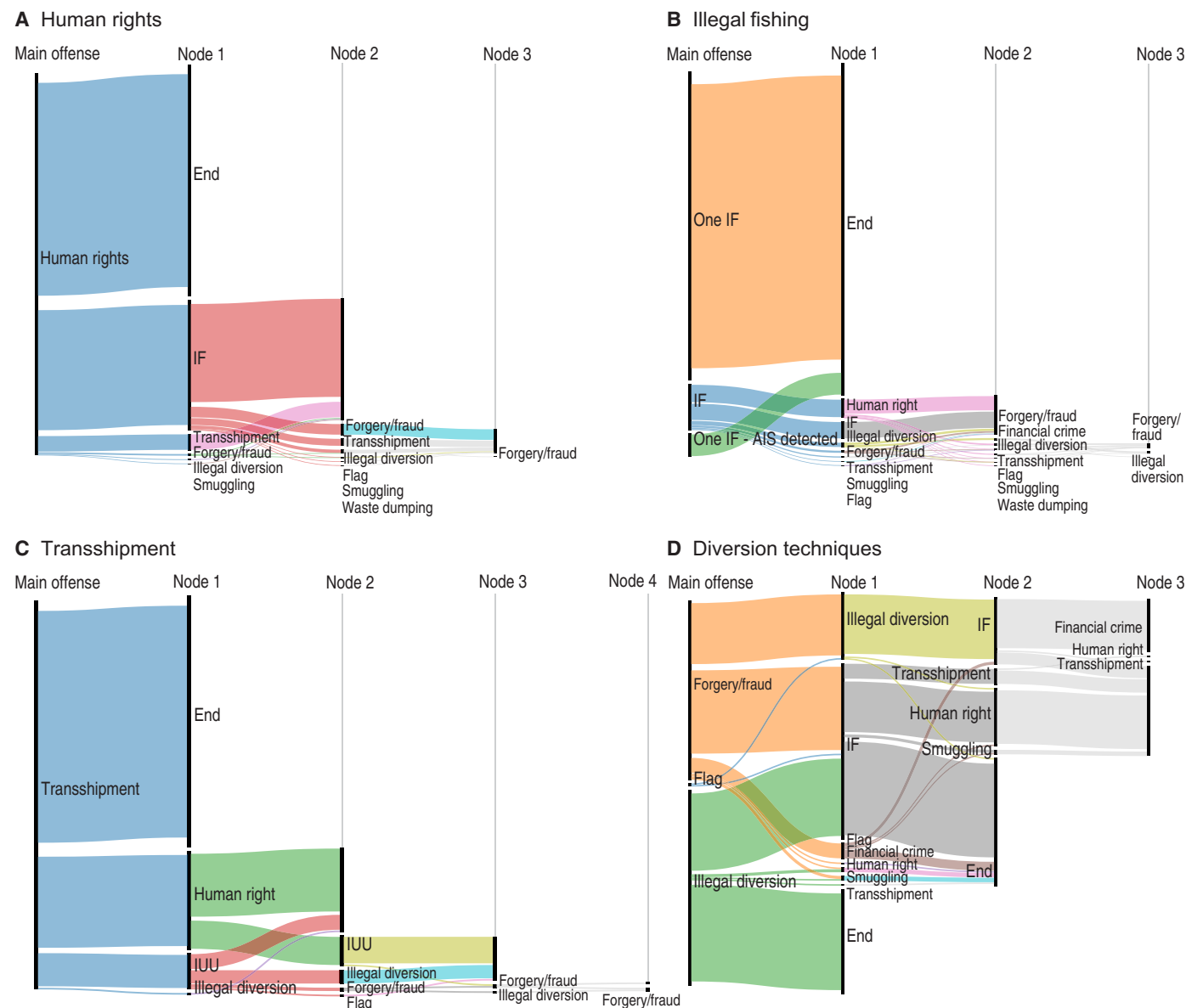


Fig. 6. Zoom into human rights and labor abuse (A), illegal fishing (B), transshipment (D) links to other offenses in fisheries, 2000–2020, and analysis of how uncertainty affects these links (C). Data are extracted from the CRFV. Each black bar is labeled with the corresponding offense category (except for the sectors' bar), the colored flow after each bar documents the category of that bar. The red shades represent illegal fishing and unauthorized offenses. Green shades represent transshipment offenses. Purple shades represent human rights and labor abuse offenses. Brown shades represent financial offenses, and yellow shades represent forgery and fraud. If a red shade (IF) is followed by a purple shade (human rights and labor abuse), then it means that those two offenses were found in a similar incident. The further a flow goes, the higher the interlinkages score, meaning multiple offenses co-occurred in that single incident.

2) Government lists, either publicly available or obtained through confidential but reliable informants from the government or third-party reports for the government. These constitute nearly 18% of the sources (95% public and 5% confidential) in the database and are considered highly reliable.

3) Witness (notably, fishers) testimonies, mainly collected through third-party investigations, such as those conducted by the Environmental Justice Foundation, Greenpeace, and others working around the issues of slavery and human rights abuses, in which case they are classified under (1) above, or from direct witnesses in only three cases

in the database. Although these are considered reliable, particularly when testimonies corroborate each other, however, they are considered under the “alleged” category.

4) Infractions detected through AIS information overlapped with geographic information on prohibited areas between 2012 and 2016, through the Global Fishing Watch platform (72), which constitute nearly 6% of the sources. This category is regarded as uncertain, given the method used and direct observation being performed. In this particular case and in the case of the Russian fleet, a ground truthing exercise revealed that all Russian vessels detected as having fished

within a prohibited zone had also infringed upon the prohibition of fishing within an artisanal zone at least once during the time period indicated above.

In this analysis, we argue that only category (4) constitutes a potential high source of uncertainty. However, given that it only constitutes a source of uncertainty for 6% of the cases, which are mainly fishing within a prohibited area, it is not expected to alter the conclusions of the previous analysis in a significant manner. The nature of the interlinkages nodes is not affected by incidents with an uncertainty score of 4 (Table 2). Hence, removing the 6% of instances does not change the trends or other findings significantly.

Uncertainty analysis was conducted for the nature of the source of the information, as per Table 4 below, and discussed other sources of uncertainty and bias. We score these sources of information for uncertainty differently, on the basis of their reliability, with a score of 1 for very low uncertainty (i.e., high reliability) and a score of 4 for very high uncertainty (i.e., low reliability). Government lists or reports score the highest, regardless of how they were obtained (e.g., only Guinea's reports on arrests are made publicly available on the Ministry of Fisheries' website). Reports from fisheries observers fall within that category, with the CRFV including 330 observer-reported infractions that were made publicly available by the RFMOs using them. Third-party reports and media reports are scored 2 (low uncertainty) because they are based on sound investigations and field verification (with or without government intervention). Information obtained through confidential informants is scored with high uncertainty at 3, as some confidential information may be very accurate but cannot be verified for certainty unless the primary evidence or an official, confidential, report is provided, and information is deducted from AIS at 4. This scoring enables the calculation of a confidence interval using a Monte Carlo approach (35).

Categorization of fisheries-related offenses

Building on studies categorizing fishing-related offenses (30, 32, 38, 39, 54, 73) (see Table 1 and tables S2 to S4), our study covers three main categories of offenses, a term that we use rather than "crime" since not all offenses fall into the legal category of "criminal offenses" in all jurisdictions, and a total of 18 subcategories (see Table 4). Each offense data point ($n = 7962$) within the Criminal Record of Fishing is associated with an incident ($n = 6853$), an offense subcategory ($n = 18$), the EEZs and regions where the offense took place ($n = 155$), and the year it took place ($n = 21$), as well as the sector (artisanal and industrial), the flag state ($n = 114$), the company or individual ($n = 1050$), and the fishing vessel ($n = 2034$) associated with the offense.

Co-occurrence analysis

After analyzing the category of offenses committed, we score each incident accordingly on the basis of the number of nodes (i.e., a vessel being caught for multiple offenses of different subcategories occurring simultaneously during the same incident; see Fig. 6). For example, if a vessel was caught for two different subcategories of offenses, then we score such incident with a transversal criminality score of 2. We also qualify, quantify the co-occurrence of such offenses, and determine the companies behind them and their owners by accessing online data platforms (e.g., Equasis.org, company websites, and corporate registries, as well as Center for Advanced Defense Studies (C4ADS), Environmental Justice Foundation reports, and Greenpeace reports).

Risk factors analysis

We then analyze the conditions in which these offenses are likely to occur by modeling them (as independent variables) against social and governance indicators, namely, unemployment, control of corruption, and government effectiveness extracted from the World Bank database for each country for 2018. We use a linear regression model where the dependent variable is set as the number of times cocriminality or a node between at least two offenses (N) as a measure of intensity occurred. Independent variables were unemployment rate (U), control of corruption (C), and government effectiveness (G), extracted from the World Bank database (e.g., Worldwide Governance Indicators), and the list of the offenses were dummy variables with binary values D_n (such as TRUE or FALSE replaced in the regression by 1 and 0, respectively). We then quantify the number of times various offenses co-occurred during the same event and present their likelihood based on the variables above

$$N = a + b_1 U + b_2 C + b_3 G + b_n \sum_{i=1}^{18} D_n$$

where a is the intercept.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at <https://science.org/doi/10.1126/sciadv.abj1927>

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