



Report

China's distant-water fishing fleet

Scale, impact and governance

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Cover photo: Workers offload frozen, net-caught tuna onto waiting trucks from a reefer cargo vessel owned by a Chinese company (Manila, Philippines). © Adam Dean

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Glossary

Automatic identification system (AIS)

A ship-borne transponder sending signals on a vessel's position, heading and speed.

By-catch

The incidental or unintended capturing or killing of non-target species while fishing for another species. By-catch can be fish, but also includes dolphins, whales, turtles and birds caught by fishing gear.

Distant-water fishing (DWF)

The commonly accepted international definition of DWF covers activities outside a nation's 200-mile exclusive economic zone (EEZ), whether on the high seas or in another nation's EEZ.

Exclusive economic zone (EEZ)

A sea area up to 200 nautical miles from the coast, within which a state claims exclusive rights over marine resources.

Flag of convenience

Describing the permitted registration by a state of a vessel owned by foreign nationals. Commonly used pejoratively to denote flag states with low environmental, safety or labour standards.

Geographic information system (GIS)

A system that acquires, stores, collects, analyses, manages and visualises spatial or geographic data.

Illegal, unreported and unregulated (IUU) fishing

A range of offences covering fishing without permission or in violation of regulations of the flag state or host nation, misreporting or failure to report catches to relevant authorities where required to do so, fishing vessels without a flag or national registration, or fishing on stocks without management measures in place.

International Maritime Organization (IMO) number

A vessel's unique number, usually maintained throughout the vessel's length of service. Not required for fishing vessels, but common on industrial fishing vessels for reasons of security, taxes, certification and insurance.

Maritime Mobile Service Identity (MMSI)

A unique identification number used in radio communications. MMSI numbers are country specific, and in principle are changed when a vessel is reflagged.

Regional fisheries management organisation (RFMO)

Multilateral organisations governing fishing interests for a specific area and/or species. While some RFMOs have a purely advisory role, most have management powers to set catch and fishing-effort limits, technical measures and control obligations.

Tonne

1,000 kilograms.

Acronyms

AIS	automatic identification system
CNFC	Chinese National Fisheries Corporation
DG SANCO	European Commission's Directorate General for Health and Consumer Protection
DWF	distant-water fishing
EEZ	exclusive economic zone
FAO	Food and Agriculture Organization
GIS	geographic information system
IMO	International Maritime Organization
ITWF	International Transport Workers' Federation
IUU	illegal, unreported and unregulated
MARA	Ministry of Agriculture and Rural Affairs
MMSI	Maritime Mobile Service Identity
PGC	Poly Group Corp.
PSMA	Port State Measures Agreement (Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing)
RCMF	Rongcheng Marine Fishery Co. Ltd.
RFMO	regional fisheries management organisation
SME	small- or medium-sized enterprise
UVI	unique vessel identifiers
VMS	vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Commission

Executive summary

Having depleted fish stocks in domestic waters, the fleets of many industrialised countries are now travelling further afield to meet the rising demand for seafood. Much of this distant-water fishing (DWF) takes place in the territorial waters of low-income countries. As well as competing against the interests of local people, DWF in low-income countries is often associated with unsustainable levels of extraction, and with illegal, unreported and unregulated (IUU) fishing activities.

China's DWF fleet is the largest in the world, and so is thought to have significant effects on the environment and socioeconomic impacts in developing countries. Although China's DWF fleet is known to be large, there is little information available about its actual size and the scale of its operations. For instance, recent assessments have produced estimates ranging between 1,600 and 3,400 vessels. In addition, it is unclear whether the Government of China has a comprehensive overview of China's DWF fleet; vessel ownership is highly fragmented among many small companies and the fleet includes vessels registered in other jurisdictions.

With information from the Krakken® database (FishSpektrum, 2018) and automatic identification system (AIS) data for 2017 and 2018, we investigated the size and operations of China's DWF fleet using big data analytic techniques, ensemble algorithms and geographic information systems (GISs).

Key findings

China's DWF fleet is 5–8 times larger than previous estimates. We identified a total of 16,966 Chinese DWF vessels. These include 12,490 vessels observed outside internationally recognised Chinese waters between 2017 and 2018.

Trawlers are the most common DWF vessel, and most vessels are in the Northwest Pacific. We identified 1,821 individual Chinese DWF vessels as trawlers. This is more than double the largest previous estimate of the number of trawlers in China's DWF fleet. An analysis of 5,241 fishing manoeuvres for 1,878 vessels during 2017 and 2018 found that the most frequent area of operations was the Northwest Pacific. However, the most intense operations were squid fisheries in the Southeast Pacific and Southwest Atlantic.

Almost 1,000 Chinese DWF vessels are registered in other countries. We identified 927 vessels with Chinese owners, operators or other Chinese interests registered in other countries. 518 of these are flagged to African nations, where enforcement measures are generally limited, and where fishing rights are often restricted to domestically registered vessels. Just 148 vessels were registered in nations commonly regarded as flags of convenience. This reflects the limited incentives for adopting flags of convenience given the relatively lax regulation and enforcement of Chinese authorities.

The ownership and operational control of China's DWF fleet is both complex and opaque. Analysis of a subsample of 6,122 vessels found that just eight companies owned or operated more than 50 vessels. The majority of vessels are owned by small- or medium-sized enterprises (SMEs). Many of these may be subsidiaries of larger corporations for tax or regulatory purposes. Labyrinthine company structures and a lack of transparency are likely to hamper monitoring and enforcement efforts, and efforts to ensure those ultimately responsible for malpractice are held accountable.

At least 183 vessels in China's DWF fleet are suspected of involvement in IUU fishing. Just 10 companies own almost half of these vessels, and several are parastatal companies. This implies

that Chinese authorities have the opportunity to target their enforcement efforts efficiently and lead by example when it comes to enforcing and prosecuting IUU activities.

Conclusions and recommendations

Chinese DWF is not solely responsible for the global fisheries crisis: other countries are also responsible for overfishing. The international community has also failed to ensure oversight of international fishing operations, such as establishing a global, centralised database of IUU vessels, and many governments in low-income countries are either unwilling or unable to monitor their waters.

However, the sheer size and global presence of its DWF fleet, as revealed in this report, means China is the most significant actor. This makes the low levels of transparency and control over the operations of its DWF fleet of particular concern. Improving the governance of this fleet is central to efforts to combat overfishing and IUU fishing, and to prevent the degradation of global fish stocks.

Our findings suggest that China faces a greater challenge than previously realised in meeting its goal to reduce its DWF fleet to 3,000 vessels. Our findings also concur with those of other researchers who have identified significant gaps in China's capacity for governing its DWF fleet. However, China can take steps to demonstrate global leadership on the governance of DWF, sustainability of global fisheries and combatting IUU.

Steps would include:

- improving the registration and transparency of DWF vessels, as well as owning and operating companies;
- adopting higher standards such as ratification of the Port State Measures Agreement (PSMA), as a flag state;
- stricter regulation and enforcement of DWF operations; and
- strengthening bilateral cooperation with states where Chinese DWF vessels fish.

Our findings also highlight the need for more effective regional and global action. International bodies and agencies can upgrade capacity for monitoring, information sharing and enforcement, take proactive measures to disrupt IUU stocks from entering international supply chains, and support governance capacity in coastal developing states. Coastal developing states that ratify international agreements increase transparency over international fishing agreements, and upgrade enforcement measures will be better able to combat resource theft and corruption.

These findings contribute to global work on the scale, impacts and governance of China's DWF fleet. More work is needed to explore the ecological, social and economic impacts of China's DWF fleet in developing countries, and to investigate the behaviour of transnational companies engaged in DWF, particularly those registered in flag-of-convenience states and tax havens.

1 Introduction

Global fishing effort has expanded rapidly since the 1950s, fuelled by technological advances, large public subsidies and increasing demand for fish protein (Tickler et al., 2018). This expansion has severely and negatively affected global fish stocks; 90% of commercially exploited marine fish stocks are now either overfished or fished to their maximum sustainable limits (FAO, 2016a).

Fishing vessels now travel further in search of declining catches. The average distance travelled has doubled since the 1950s, with catches falling from 25 kg per kilometre travelled to 7 kg per kilometre over the same period (Tickler et al., 2018). As fishing fleets have exhausted fish stocks in the waters of advanced economies, they are hunting further afield, particularly in the waters of low-income countries (Pauly, 2008). A recent analysis found that in the exclusive economic zones (EEZs) of low-income countries, 84% of industrialised fishing effort came from other countries and 78% came from vessels flagged to higher- and upper-middle-income nations (McCauley et al., 2018).

Distant-water fishing (DWF) often competes with the interests of people in low-income nations (Toppe et al., 2017). Economically weak countries in need of foreign currency, and without their own industrial fleets or scientific advice on sustainable catch limits, often negotiate disadvantageous fisheries agreements (Belhabib et al., 2014). Fragile governance and weak enforcement mean that low-income countries are also most at risk from widespread problems of illegal, unreported and unregulated (IUU) activities that accompany DWF fleets (Agnew et al., 2009; Daniels et al., 2016). For example, 20% of the global IUU catch is estimated to come from just six contiguous West African countries (Mauritania, Senegal, The Gambia,

Guinea-Bissau, Guinea and Sierra Leone).

The opportunity cost of IUU activities to the economies of these six countries has been estimated at \$2.3 billion a year and 300,000 jobs (Daniels et al., 2016; Belhabib, 2017).

As such, DWF poses risks to the sustainable use of marine resources in low-income countries, and to the income, employment and food security of people dependent on these resources (Toppe et al., 2017).

This report examines the size, composition and operations of the Chinese fleet capable of DWF.¹ We focus on China as it is the dominant force in the global fishing industry, with the largest domestic and DWF fleets; China is also the world's largest producer of fish products (Pauly et al., 2014; Mallory, 2012; 2013).

Despite the significance of China's fishing industry, assessment of its size and operations is hampered by a lack of transparency and by the limited availability of information in English (Mallory, 2013). Even estimates of the size of China's DWF fleet vary considerably: from under 2,000 vessels (Mallory, 2013) to around 3,400 vessels (Pauly et al., 2014). Information on the geographic location, types of fishing and catches of the Chinese DWF fleet is also limited.

The gaps in data on China's DWF fleet are concerning. They constrain understanding and mitigation of the ecological and socioeconomic impacts of the fleet's activities in specific territories and undermine effective global and multilateral governance.

This report sets out to address some of these knowledge gaps about the size and operations of China's DWF fleet. We hope that our findings will be of interest to research and policy communities aiming to improve the governance, monitoring, surveillance and sustainability of global fisheries.

1 When referring to China, we mean the People's Republic of China, excluding Chinese Taipei/Taiwan and the Special Administrative Regions of Hong Kong and Macau.

We set out to answer four key questions:

1. How big is the Chinese DWF fleet?
2. Where and how is it operating?
3. Where are these vessels registered, and who is operating them?
4. What are the implications of the DWF fleet's activities for sustainable development?

Chapter 2 gives more information on China's role and on previous studies. Chapter 3 summarises our methodology, followed by Chapter 4, which presents our five main findings. After a brief analysis of the development implications of our findings (Chapter 5), we present our conclusions and key policy recommendations in Chapter 6.

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2 Background

2.1 China as a global fishing superpower

China is a fisheries superpower. It has the largest fishing fleet and the largest DWF fleet in the world. In 2016, China captured 15.2 million tonnes of fish – around 20% of the global total – and consumed 38% of total global fish production. China's DWF caught two million tonnes, although China provided details of species and fishing area for only those catches marketed in China, representing 24% of the DWF catch (FAO, 2018a). In the same year, China exported fish and fish products worth \$20.1 billion – around 14% of the total global trade (FAO, 2018a).

A relative latecomer to DWF, China began overseas fishing in 1985 when 13 vessels of the China National Fishing Corporation set sail for West Africa (Mallory, 2013). Since then, the number of Chinese DWF vessels has grown rapidly. As with other DWF fleets, this growth is driven by increasing demand for fish outstripping local supply. By 2012, 30% of fisheries in China had collapsed, and 20% were considered over-exploited (European Parliament, 2012).

Like those of other countries, China's push to expand its DWF fleet has been fuelled by tax exemptions and subsidies for fuel and ship construction (Mallory, 2013; Kang, 2016). Fuel subsidies have been a particularly important component of this boom, given the long trips from ports in China to distant fishing waters (Kang, 2016).

2.2 Knowledge gaps and questions

As mentioned in the introduction, understanding of the size and operations of China's DWF fleet is constrained by a range of issues. One is a lack of transparency. For example, developing bottom-up estimates of China's DWF activities is difficult, as bilateral fishing agreements governing Chinese

vessels in the waters of other nations are rarely publicly available (Pauly et al., 2014).

Conservation organisation Oceana has described the lack of transparency in the activities of China's DWF vessels:

(They) operate largely without access agreements or under access agreements that are secret, thus we don't even know if their catch is legal or not ... There are good reasons to think that China's distant water fleets, legally or not, catch well above the surplus in the countries where they operate. Chinese authorities are not publishing catch statistics or evaluations of the stocks exploited by their fleets. (Oceana, 2013)

Another key constraint is the limited availability of information in English (Mallory, 2013).

In this section we summarise what is already known about Chinese DWFs and provide an overview of key knowledge gaps.

2.2.1 Fleet size

The size of China's DWF fleet has been reported as: 1,899 and 1,989 vessels in 2010 and 2011 (Mallory, 2013); approximately 1,600 vessels with over 30,000 crew in 2013 (European Commission, 2016); and around 3,432 vessels (Pauly et al., 2014) or 2,460 vessels (Greenpeace, 2016a) in 2014. In comparison, the European Union's DWF fleet was 289 vessels in 2014, and the United States had 225 large DWF vessels in 2015 (Kang, 2016). Estimates of China's DWF fleet generally focus on Chinese flagged vessels, and there is limited data available on the number of Chinese-owned or joint venture vessels flagged in other countries.

The Chinese government does appear to recognise concerns about the size of its DWF fleet. At the 2017 World Trade Organization

summit in Buenos Aires, the Chinese government announced plans to restrict the size of its DWF fleet to 3,000 vessels by 2020, and to limit catches to 2.3 million tonnes per year (Chun, 2018). This cutback is part of China's Thirteenth Five-Year Plan for Economic and Social Development (2016–2020), which also specifies reductions in diesel fuel subsidies and the elimination of IUU fishing (FAO, 2018a).

Another question is the extent to which the government of China has a comprehensive overview of the DWF fleet. Some 70% of the fleet is now in private ownership, with the majority of vessels owned by a proliferation of small- or medium-sized enterprises (SMEs) rather than large, state-owned firms (Mallory, 2013). Fragmented ownership, joint venture operations and reflagging of vessels seem likely to challenge the state's ability to monitor the position and activities of all vessels in China's extensive fleet.

2.2.2 Geographical presence

Information on the geographical presence of China's DWF is also limited. Mallory (2013) developed a limited picture by compiling information from various official Chinese public and industry sources. In this picture, in 2010, 732 Chinese vessels operated in the waters of eight Asian countries (mostly North Korea, Indonesia and Myanmar) and 394 Chinese vessels operated in 11 African countries, with larger fleets in Mauritania, Guinea and Morocco (Bureau of Fisheries, 2011, in Mallory,

2012). Another report from 2010 refers to 202 trawling vessels in West Africa (Supporting and Strengthening Distant-water Fisheries Task Force, 2011, in Mallory, 2012). Mallory (2012) also refers to Chinese vessels operating throughout the Pacific and Southwest Atlantic, without giving figures.

Taking a bottom-up approach, based on Chinese vessels reported in different territories, including in various bilateral fisheries agreements, Pauly and colleagues calculated that China operated 2,745 DWF vessels in Asia, mainly in the waters of Japan and South Korea, and 393 vessels in West and East Africa, with smaller numbers of vessels operating in Oceania, Central and South America, and Antarctica (Pauly et al., 2014). While Mallory's and Pauly et al.'s figures for vessels operational in Africa are strikingly similar (394 vs 393), their figures for DWF vessels in Asia are wildly different (732 vs 2,745).

2.2.3 Vessel types and target species

Information about the fishing gear and target species of China's DWF fleet is similarly inconclusive. For example, various sources agree that trawlers are the most common type of vessel, but figures range from 40% (Pauly et al., 2014; Agriculture Bureau of Fisheries, 2011, in Mallory, 2013) to 60% (Lam et al., 2011, in Pauly et al., 2014). Estimates and reports for other types of gear are similarly inconsistent, not helped by the different systems used for classifying vessels.

3 Data and methodology

The methodology underlying this study combines the use of big data analytic techniques, ensemble algorithms and geographic information systems (GISs).

We extracted data from the FishSpektrum Krakken® database (FishSpektrum, 2018) on all possible DWF vessels with connections to China (Box 1). Annex 1 describes the methodology in more detail. We developed our own database to define and categorise Chinese vessels capable of DWF, and compared our data with findings in other expert literature.

We also used GIS software to visualise automatic identification system (AIS) data and identify fishing manoeuvres according to their location and movement patterns (Annex 2). Based on expert knowledge, these fishing manoeuvres were labelled to train algorithms to detect patterns in the location data. We used an ensemble of learning algorithms to identify where and how vessels operate when fishing. Finally, we combined all the analysis with other sources on IUU fishing.

Descriptive and dynamic data limitations are the leading methodological constraint on our findings. The Krakken® dataset contains gaps, including missing information on regional fisheries management organisation (RFMO) registration, vessel type, International Maritime

Organization (IMO) and ownership. This implies that our figure for the size of China's DWF fleet may be an underestimate. Another possible cause for an underestimate are gaps in the dynamic data, with AIS data unavailable for 2,462 (14.5%) of Chinese-registered vessels.

Box 1 Identifying China's distant-water fishing vessels

The DWF vessels of one country are those operating within the EEZs of another country, or further offshore on the high seas (Oceana, 2013). However, identifying which vessels are operating where is not simple.

To identify Chinese DWF vessels, we looked at records of vessels: registered with specific Chinese public agencies responsible for regulating DWF; registered with foreign governments; or inspected outside Chinese waters. We also looked at vessels' unique Maritime Mobile Service Identity (MMSI) transponders being detected as active outside Chinese waters on a sample of dates during 2018. The methodology is described in more detail in Annex 1.

4 Findings and implications

Our analysis of the data has identified five key findings:

1. China's DWF fleet is 5–8 times larger than previous estimates.
2. Trawlers are the most common DWF vessel, and most vessels are in the Northwest Pacific.
3. Almost 1,000 Chinese DWF vessels are registered in other countries.
4. The ownership and operational control of China's DWF fleet is both complex and opaque.
5. At least 183 vessels in China's DWF fleet are suspected of involvement in IUU fishing.

4.1 China's DWF fleet is 5–8 times larger than previous estimates

We identified 16,966 vessels in the Krakken® database as members of China's DWF fleet (Table 1). This is 5–8 times larger than the estimates of 1,989 vessels provided by Mallory (2013), 3,432 vessels by Pauly et al. (2014), or 2,460 vessels by Greenpeace (2016b).

The largest subgroup we identified was of 12,490 vessels without IMO or RFMO registrations but with active AIS signals outside Chinese waters at some point between 1 January 2017 and 31 December 2018.

Table 1 Identifying China's distant-water fishing fleet in the Krakken® database

Extraction	1	2	3	4.1	4.2	4.3	6.1	6.2	6.3	6.4
Registered IMO or RFMO number	✓	✗	✗	✓	✓	✓	–	–	–	–
Registered RFMO number	–	✓	✗	–	–	–	–	–	–	–
Registered with Chinese DWF Association	–	–	–	–	–	–	–	–	–	✓
AIS signal outside Chinese EEZ in 2017 or 2018	–	–	✓	–	–	–	–	–	–	–
Currently flagged to China	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓
Not currently flagged to China	–	–	–	✓	✓	✓	–	–	–	–
Previously flagged to China	–	–	–	–	✓	–	–	–	–	–
Never flagged to China	–	–	–	–	–	–	✓	–	–	–
Inspected by Chinese authorities outside Chinese waters in 2018	–	–	–	–	–	–	–	✓	–	–
Exported or impounded by Customs	–	–	–	–	–	–	–	–	✓	–
Built in China	–	–	–	✓	✗	✗	–	–	–	–
Related to Chinese interests	–	–	–	–	–	✓	✓	–	–	–
Number of vessels	2,076	575	12,490	431	92	86	318	379	82	437

Source: elaborated from FishSpektrum (2018).

We assume that this remote observation of a vessel's presence overseas grants high confidence that it is engaged in DWF operations. If we consider only this group – discounting all other results – the figure of 12,490 vessels is still 3.5 times larger than the estimate of Pauly et al. (2014).

We also identified 3,541 vessels with either a registered intention to fish overseas or in contact with Chinese enforcement agencies in circumstances that strongly imply engagement in DWF fishing. These included Chinese-flagged vessels: with IMO numbers (Extraction 1), registered with RFMOs (Extraction 2), registered with the Chinese DWF association (Extraction 6.4), inspected by Chinese authorities outside Chinese waters during 2018 (Extraction 6.2), or registered as exported or seized by Chinese customs agents (Extraction 6.3).

Additionally, we identified 927 vessels flagged by other countries that have associations with China that we assume are significant. These include vessels built in or previously flagged to China, or with a Chinese interest, meaning that they have a current or previous Chinese name, operator or owner. These vessels may be flagged to other nations but were operated by Chinese businesses or their subsidiaries, contributing to China's supply chains and international fishing effort.

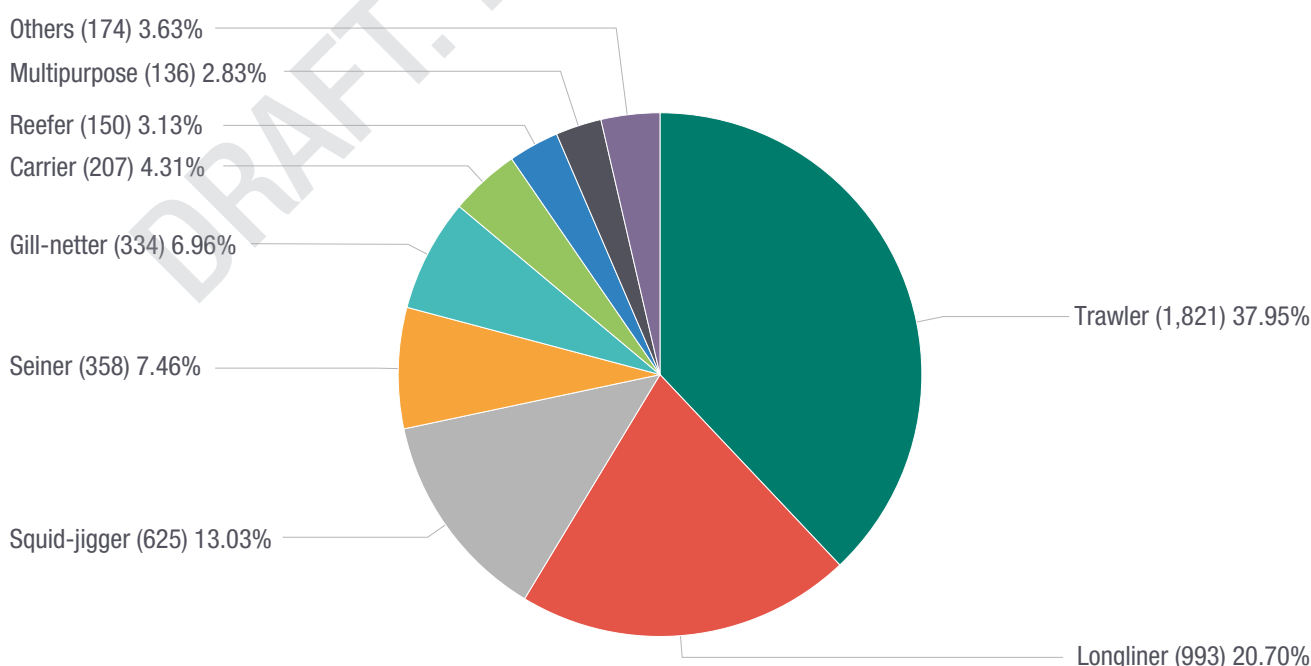
Our identification of vessels as members of the DWF fleet does not imply that all are operating currently, simultaneously or consistently in foreign or international waters. This is partly due to gaps in the available data, and partly due to the criteria used to identify the DWF fleet. Krakken®'s records are not updated in real time and do not reflect the current status of some vessels. For example, Krakken® may record a vessel as being operational during 2017, but not record that it was decommissioned in early 2018. There are 58 Chinese vessels whose last record in Krakken® was 'active and operational' before 1989; these vessels may no longer be operational.

4.2 Trawlers are the most common DWF vessel, and most vessels are in the Northwest Pacific

4.2.1 Numbers of DWF trawlers

Krakken® contains details on the type of vessel for 4,798 of the DWF vessels we identified. Of these, 1,821 (38%) were trawlers, 993 (20.7%) were long-liners, 625 (13%) were squid-jiggers, 358 (7.5%) were seiners, and 334 (7%) were gill-netters. A further 667 vessels (13.9%) were of other types or served in support roles (Figure 1).

Figure 1 Type of vessel for a sample of 4,798 Chinese distant-water fishing vessels



Source: elaborated from FishSpektrum (2018).

This picture contrasts with the current composition of the global high seas fleet, in which 59% of vessels are thought to use long-lines (Sala et al., 2018). However, the proportions in our sample are reasonably consistent with previous estimates of the composition of the Chinese DWF fleet as shown in Table 2, all of which conclude that trawlers are the dominant type of gear carried.

As we cannot assume that our sample is representative of China's DWF fleet, we have not extrapolated these results. The figure of 1,821 trawlers is therefore highly conservative; the actual number of trawlers in China's DWF fleet may be considerably higher.

Despite this uncertainty, our subsample of 1,821 trawlers is still more than double the largest previous estimate, in Mallory (2013). Trawlers are of particular interest, as one form of trawling – bottom-trawling – is a highly destructive fishing technique. Bottom-trawling is unselective and produces excessive by-catch. It is associated with long-term damage to ecosystems in and around the seafloor (Gianni et al., 2016; Safina, 2016; WWF, 2019). While we do not know how many of these 1,821 Chinese DWF

trawlers are engaged in bottom-trawling, there is evidence that it is a common practice for Chinese trawlers in West Africa (e.g. Greenpeace, 2016b; EJJ, 2018a). That China may have well over 1,000 DWF trawlers more than previously recognised heightens concerns about the fleet's global ecological impact.

4.2.2 DWF vessels in the Northwest Pacific region

Based on AIS position data, we detected 5,241 individual fishing manoeuvres for 1,878 vessels during 2017 and 2018.² This allowed us to assess their areas of operations with a high degree of certainty, and also to classify their behaviour using algorithmic methods. The majority of these vessels were active in different areas of the Pacific, particularly the Northwest, Western Central and Southeast Food and Agriculture Organization (FAO) regions. Table 3 summarises the behaviour exhibited by vessels in each FAO fishing area.

The number of vessels present in an area does not necessarily indicate the intensity of fishing effort taking place, however. Using the density of AIS signals as a proxy for fishing effort by the

Table 2 The composition of China's distant-water fishing fleet

Source	Sample size	Squid-jiggers	Trawlers	Tuna long-liners	Tuna purse-seiners	Purse-seiners	Others	Criteria
ODI, based on FishSpektrum (2018)	4,798	625 (13%)	1,821 (38%)	993 (20.7%)	NR	358 (7.5%)	1,001 (20.9%)	Chinese DWF vessels for which there is data on gear type
Lam et al. (2011), in Pauly et al. (2014)	444	NR	269 (60.6%)	21 (4.7%)	40 (9%)	62 (14%)	52 (11.7%)	Chinese DWF vessels (2005)
Pauly et al. (2014)	900	NR	359 (39.9%)	261 (29%)	48 (5.3%)	49 (5.4%)	183 (20.3%)	Chinese DWF vessels operating in EEZ (and adjacent high sea) (2000–2011), excluding vessels in Japan and South Korea
Ministry of Agriculture Bureau of Fisheries (2011), in Mallory (2013)	1,800	500 (27.8%)	800 (44.4%)	400 (22.2%)	–	100 (5.6%)	–	Chinese DWF vessels (approximate numbers, 2007)

Source: elaborated from AIS data provided by Vulcan's SkyLight.

² Just 13% of the vessels with active AIS signals had sufficient data to detect clear fishing manoeuvres. This may be because vessels fishing on the high seas may be undetected by AIS receivers, and/or vessels may deactivate or tamper with their AIS transponders (Gutierrez et al., 2018).

Table 3 Fishing operations observed in each global region during 2017 and 2018

Region	FAO code	Trawling	Long-lining	Squid-jigging	Total fishing operations
Pacific, Northwest	61	1,277	684	1,018	2,979
Pacific, Western Central	71	182	133	252	567
Pacific, Southeast	87	142	119	163	424
Atlantic, Southwest	41	102	98	181	381
Pacific, Eastern Central	77	63	66	69	198
Indian Ocean, Western	51	54	45	104	203
Atlantic, Eastern Central	34	43	31	54	128
Indian Ocean, Eastern	57	32	18	58	108
Atlantic, Southeast	47	17	17	37	71
Atlantic, Western Central	31	15	15	12	42
Pacific, Southwest	81	12	18	21	51
Atlantic, Northeast	27	10	8	18	36
Mediterranean and Black Sea	37	7	2	22	31
Atlantic, Antarctic	48	4	2	4	10
Arctic Sea	18	1	1	1	3
Atlantic, Northwest	21	1	0	4	5
Indian Ocean, Antarctic and Southern	58	1	1	2	4

Note: we did not detect any Chinese fishing in Area 88 (Pacific, Antarctic).

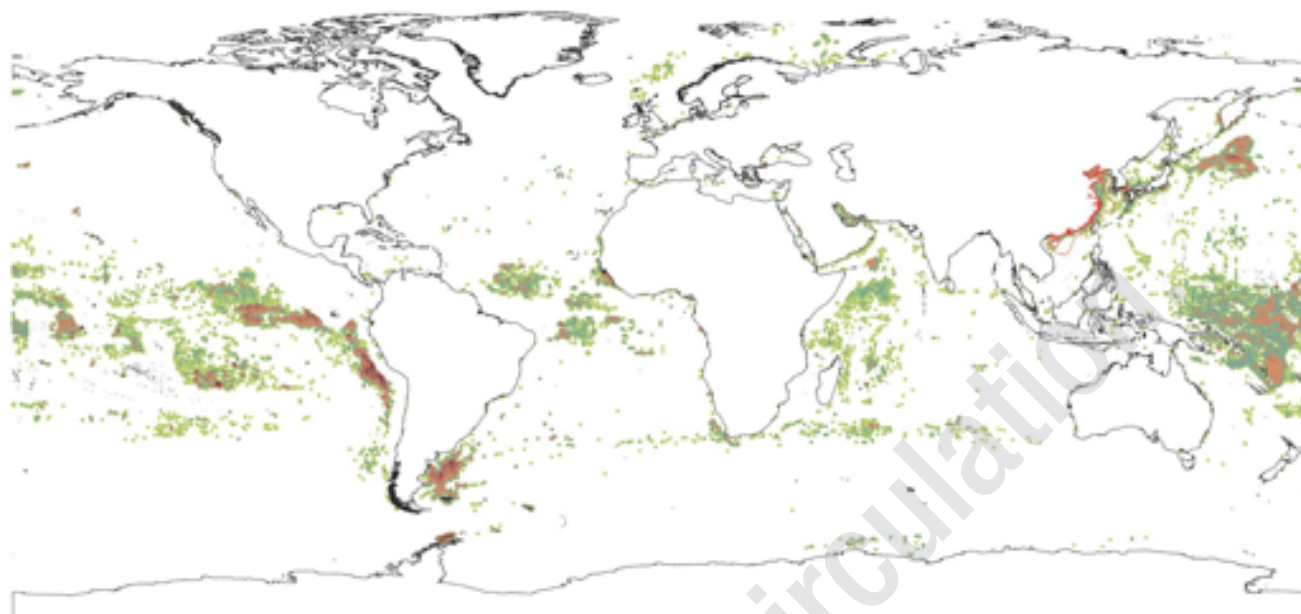
1,878 vessels shows that fishing effort is most intense in the Southwest Atlantic and Southeast Pacific regions (Figures 2,3,4,5). These two areas, and particularly the Southeast Pacific, are associated with nutrient-rich cool-water currents and productive squid fisheries (FAO, 2005) (Figure 5). Trawling is widespread, but mostly of low intensity, and is clearly taking place in deep offshore areas as well as areas vulnerable to bottom-trawling (Figure 3).

This sample of 1,878 vessels represents only around 11% of the total DWF fleet identified in our study, so is not necessarily representative. However, the concentration of individual vessels in the Northwest Pacific (Table 3) and the extensive presence in the Yellow and East China Seas (Figure 2) are consistent with expectations. These findings are also broadly consistent with those of Pauly and colleagues (2014), who found that the majority of Chinese DWF vessels operate in Korean and Japanese waters.

Different definitions of national and distant waters could be one possible factor underlying the large discrepancy between the 16,966 Chinese DWF vessels we have found and the much smaller numbers offered by the Government of China and other reports. China claims large areas in the Yellow, South and East China seas as national waters. These areas and claims are not internationally recognised as part of China's EEZ. China does not consider fishing operations outside its EEZ but within these claimed areas to be DWF, and so does not include them in reports on its DWF fleet or operations (Zhang, 2015). However, one criterion for inclusion in our DWF list (as described in Chapter 3 and Annex 1) was a detectable AIS position outside China's internationally recognised EEZ during 2017 or 2018. For this reason alone, 12,490 Chinese-flagged vessels were added to our list.³ However, it seems unlikely that different definitions of fishing areas account for the whole disparity.

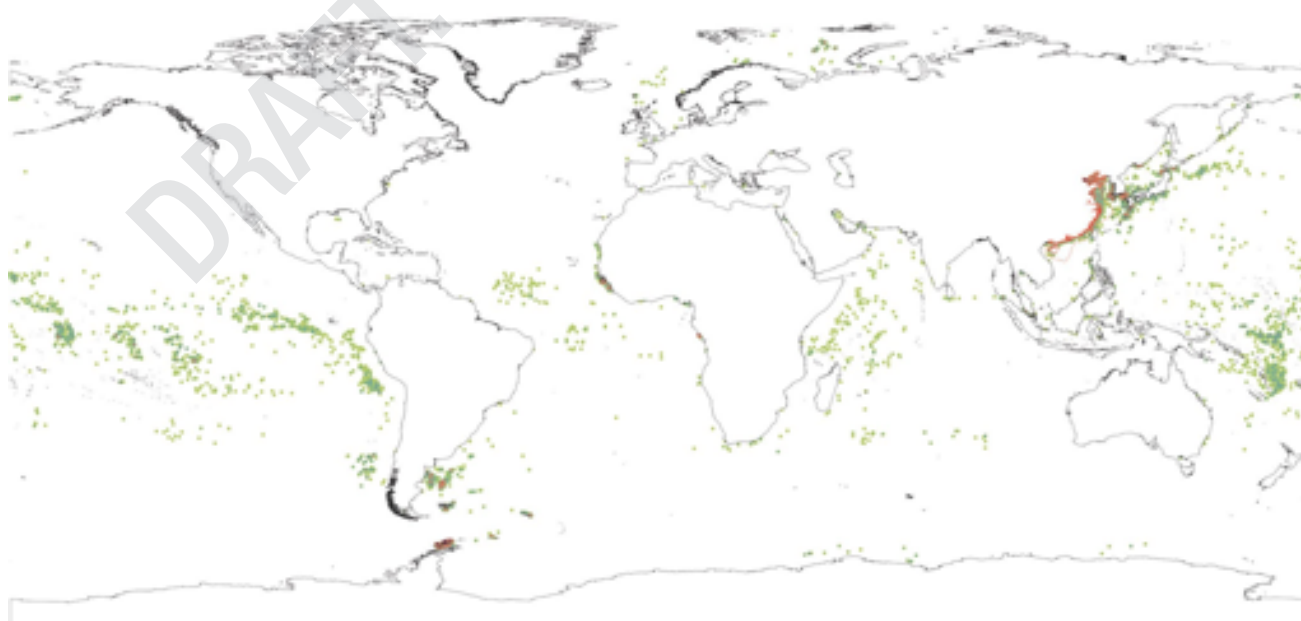
³ These vessels have no IMO registration number, and are not registered with an RFMO or the Chinese DWF association.

Figure 2 Intensity of fishing activity by China's distant-water fishing fleet



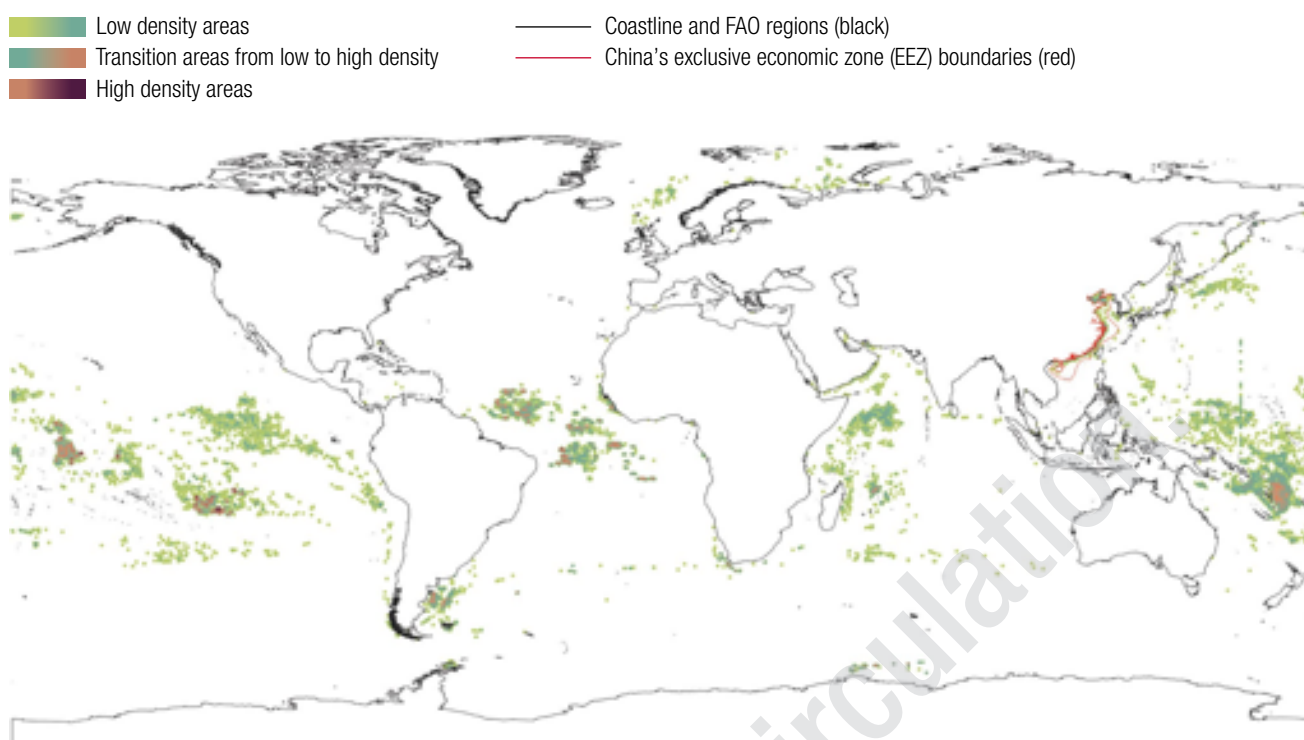
Source: elaborated from AIS data provided by Vulcan's Skylight.

Figure 3 Intensity of trawling activity by China's distant-water fishing fleet



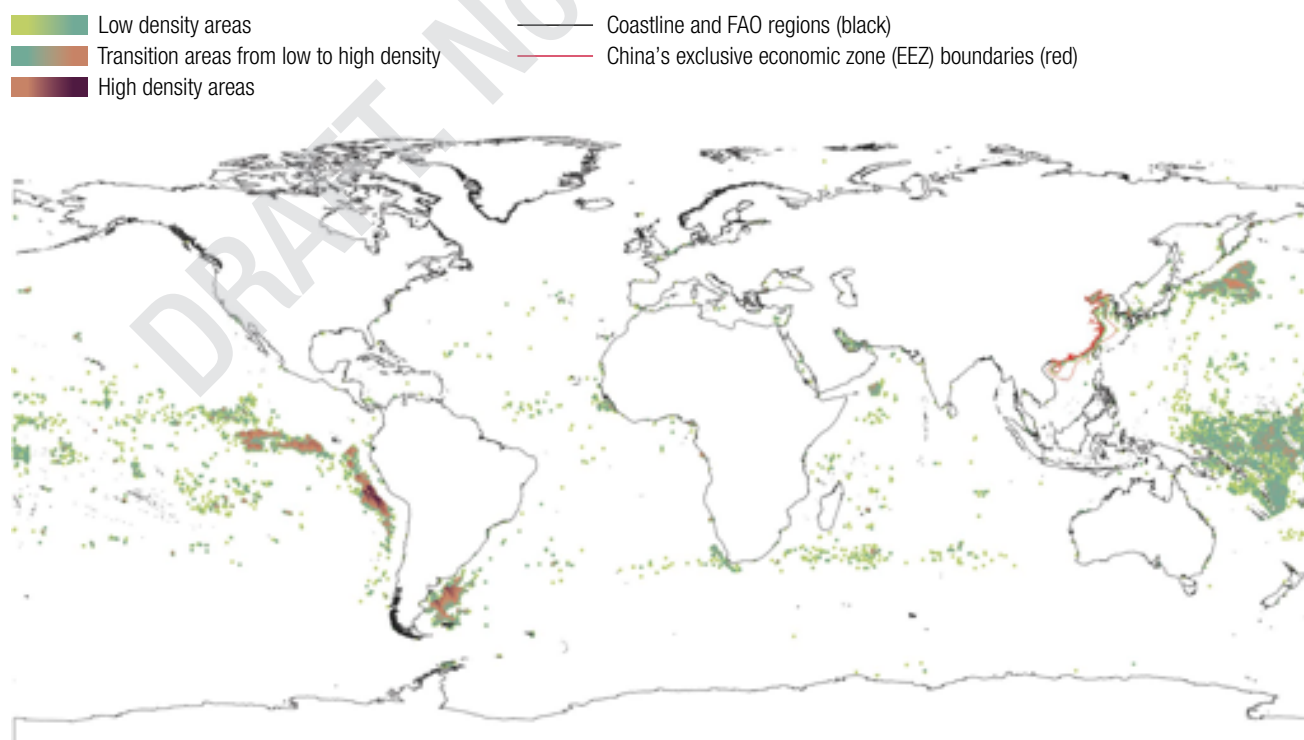
Source: elaborated from AIS data provided by Vulcan's Skylight.

Figure 4 Intensity of long-lining activity by China's distant-water fishing fleet



Source: elaborated from AIS data provided by Vulcan's Skylight.

Figure 5 Intensity of squid-jigging activity by China's distant-water fishing fleet



Source: elaborated from AIS data provided by Vulcan's Skylight.

4.3 Almost 1,000 Chinese DWF vessels are registered in other countries

4.3.1 Registration of Chinese vessels to other countries

Of the 16,966 vessels in China's DWF fleet, 16,039 (94.5%) sail under a Chinese flag and only 927 (5.5%) are flagged to a third country or no country (Figure 6).⁴ Although 927 is a large number, it is a relatively small proportion of the global fleet; around 20% of the world's fishing vessels are registered in states to which they have no other connection (DeSombre, 2006).

The Chinese DWF fleet includes vessels flagged to 56 countries outside China. The five most frequent non-Chinese flags states – Ghana, Mauritania, Côte d'Ivoire, Fiji and Panama – account for almost half the total (48%, or 445 vessels).

4.3.2 Chinese vessels flagged to Africa

Of the 927 vessels flagged in countries other than China, we found 518 Chinese DWF vessels registered in African nations. The vast majority of them – 92.7% (480 vessels) — fly the flags of countries on Africa's west coast between Gabon

and Morocco (Figure 7). More than half of these vessels are registered in just two countries: Ghana and Mauritania.

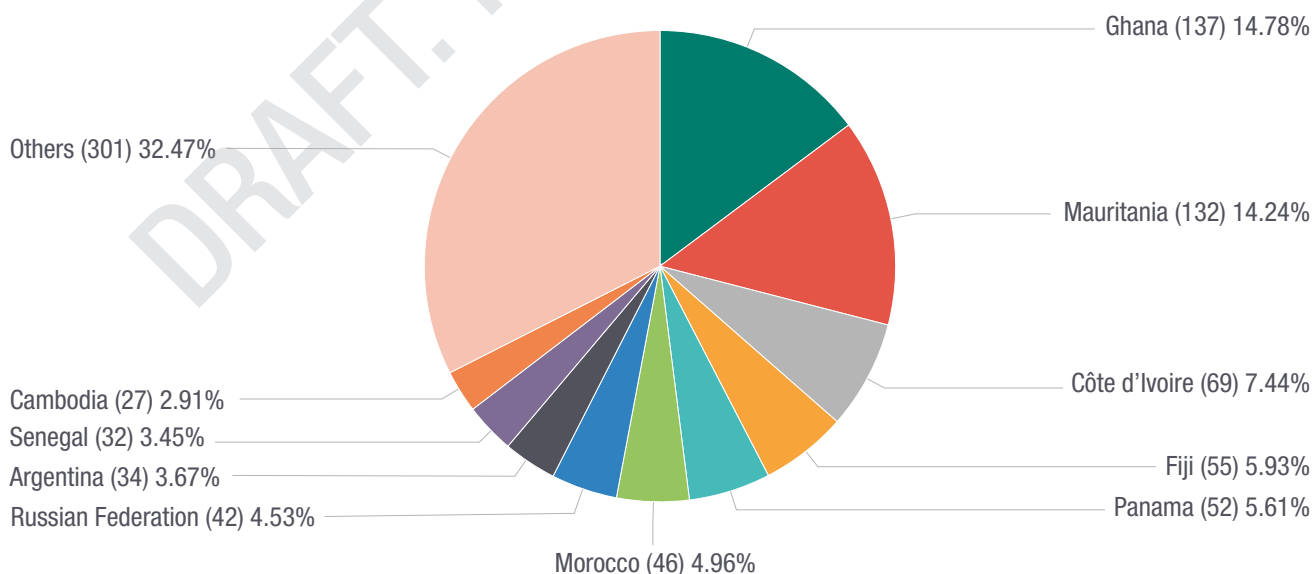
Registration in Ghana most likely reflects a technical compliance with laws restricting industrial and semi-industrial fishing in Ghanaian waters to Ghanaian-flagged vessels that are not owned or part-owned by foreign interests, except in the case of tuna trawling (Republic of Ghana, 2002). (For more information on this, see the box in Chapter 5 of this report.) Similarly, Chinese firms are alleged to reflag vessels in Mauritania as part of private agreements brokering investment for access to fisheries resources (Transparent Sea, 2012; Marti, 2018).

Of the 518 Chinese DWF vessels registered in Africa, 82% (426 vessels) are trawlers. Some authors have alleged that restrictions by Chinese authorities on trawlers have encouraged Chinese trawlers to relocate to waters with weaker enforcement capacity (e.g. Chintom, 2016; Ogundej, 2019).

4.3.3 Foreign-registered vessels under flags of convenience

Of the 927 foreign-registered Chinese vessels, 148 are registered in countries considered to be providing flags of convenience, including

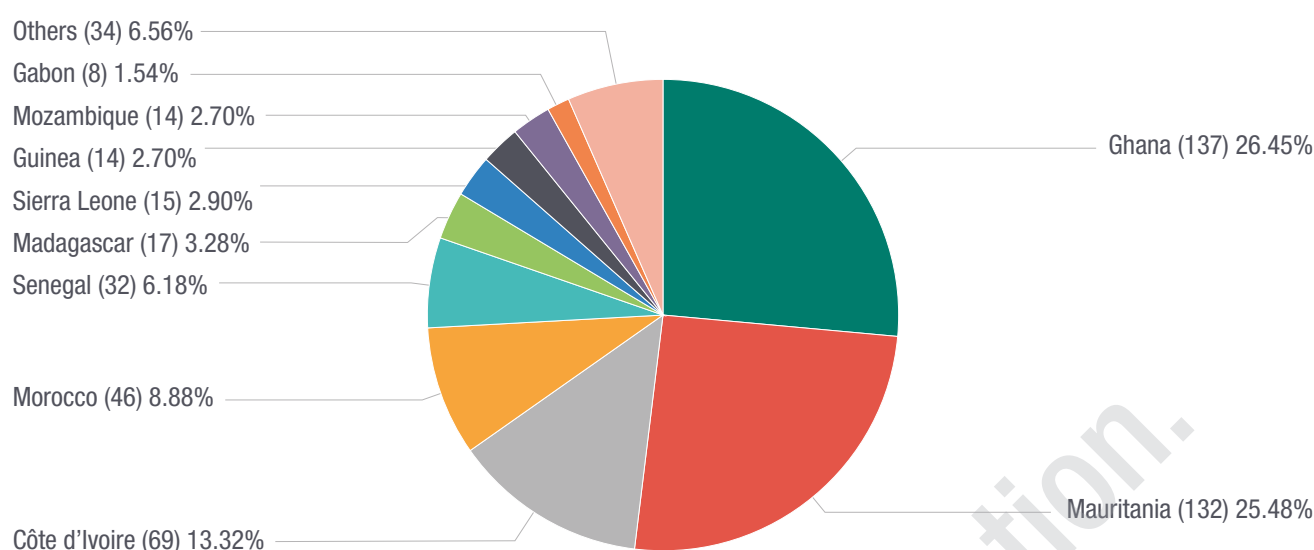
Figure 6 The 10 most common foreign-flag states for Chinese distant-water fishing vessels



Source: elaborated from FishSpektrum (2018).

⁴ Krakken® does not show flag data for 15 of the DWF vessels.

Figure 7 Chinese distant-water fishing vessels flagged to African countries



Source: elaborated from FishSpektrum (2018).

Panama, Cambodia, Belize, Vanuatu, St Vincent, Honduras and Liberia (Figure 8).⁵ Flags of convenience have legitimate uses, but are also routinely used by ship owners to evade taxes and regulations of their home state, such as for safety and environmental standards and/or workers' rights.

Flags of convenience can also help to protect vessel owners from legal action or scrutiny, particularly by obscuring who actually owns vessels engaging in illicit activity (Brush, 2019). Several of these flag-of-convenience nations – particularly Panama, Belize, Liberia and St Vincent – are also recognised tax havens (discussed in Section 4.4).

4.3.4 Chinese DWF vessels retaining Chinese flags

More than 90% of China's DWF vessels fly the Chinese flag. Why do so few Chinese vessels register with flags of convenience or flags of other nations? One answer may be that there are limited incentives to do so, as China's regulation of its DWF activities is notably less vigorous

than the regulation of its own domestic fisheries (Mallory, 2013); China is effectively its own flag of convenience.

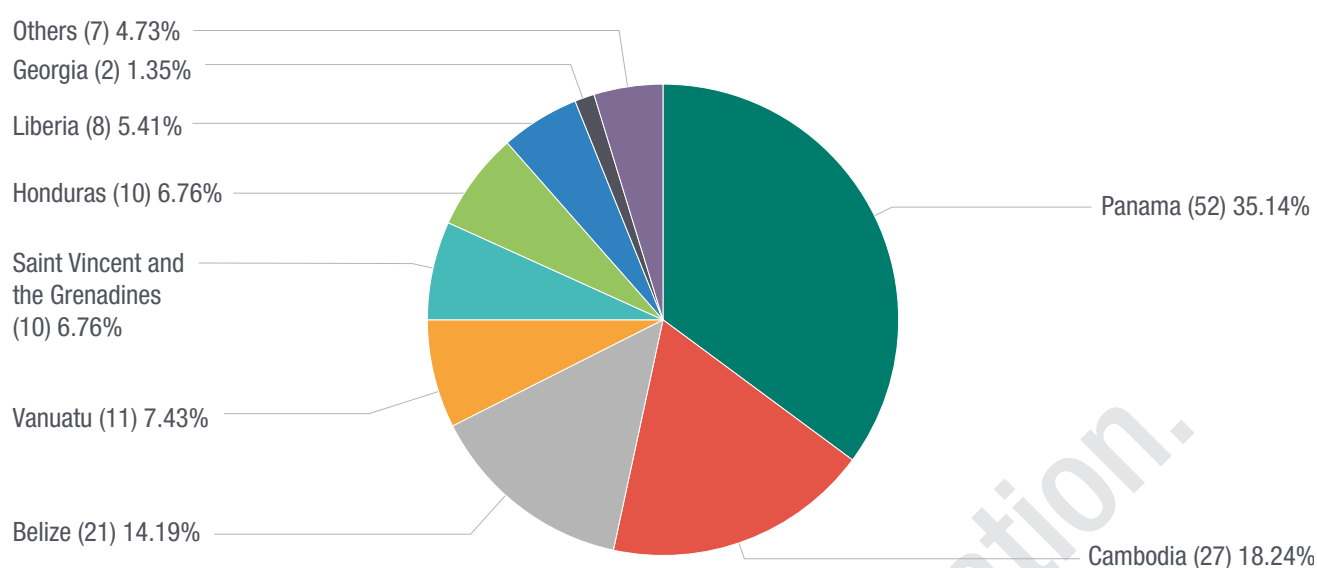
As a flag state, China does not have a particularly strong record of engaging with the international community and complying with RFMO obligations (Hosch, 2019; Macfadyen et al., 2019). Half of China's DWF vessels are believed to operate in areas governed by RFMOs. These regional organisations are typically established to manage migratory species that move across national jurisdictions and international waters and therefore require global management to prevent overfishing (Kang, 2016). However, China has joined only seven RFMOs,⁶ while, in comparison, the EU participates in 17 such organisations.

China has also been accused of attempting to set high historical fishing records, which would then serve as a basis to allocate national shares of fish stocks, taking advantage of the fact that RFMOs are usually governed by consensus (Pew, 2012). This 'race to fish' happened, for example, during negotiations of the South Pacific albacore

⁵ Based on the list of flags of convenience issued by the International Transport Workers' Federation (ITWF) in 2019 (ITWF, 2019).

⁶ These are: the International Commission for the Conservation of Atlantic Tunas, the WCPFC, the Inter-American Tropical Tuna Commission, the Indian Ocean Tuna Commission, the South Pacific Regional Fisheries Management Organization, the North Pacific Fisheries Commission and the Commission for the Conservation of Antarctic Marine Living Resources (MARA, 2019).

Figure 8 Flags of convenience favoured by the Chinese DWF fleet



Source: elaborated from FishSpektrum (2018).

fishery, under the remit of the Western and Central Pacific Fisheries Commission (WCPFC) (Kang, 2016). During the WCPFC 2014 annual meeting, the Chinese delegates insisted on increasing the Chinese DWF fleet in the area from 100 to 400 vessels before agreeing to any limits, despite scientists' concerns over the status of the albacore population (Kang, 2016).

China has failed to endorse some fundamental marine conventions, such as the Fund for Compensation for Oil Pollution Damage of 1992 (International Chamber of Shipping, 2019), the Forced Labour Convention (1930) and the Freedom of Association and Protection of the Right to Organise (1948) (ILO, 2017). As of March 2020, China had still not ratified the legally binding Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing (PSMA), unlike other significant fisheries powers such as the EU and the United States (FAO, 2019a). This agreement was approved by the FAO Conference in 2009 and came into force in 2016, aiming to strengthen controls in ports where the fisheries catches are landed and reported, and denying access to vessels suspected of IUU activity (FAO, 2019b).⁷

Further, China has been criticised for insufficient action to sign, ratify and enforce

international agreements and standards aimed at tackling IUU fishing (Mallory, 2013; Macfadyen et al., 2019), poor working conditions and human slavery (Global Slavery Index, 2018) and non-compliance with reporting requirements (Blomeyer et al., 2012; Mallory, 2013).

These positions by the Chinese state confer technical and financial advantages to the owners and operators of Chinese vessels, reducing their incentives to re-register vessels to flag-of-convenience nations.

4.4 The ownership and operational control of China's DWF fleet is both complex and opaque

4.4.1 Information on ownership of China's DWF fleet

The Krakken® shipping database offers information on the most recent operators and owners of 6,122 vessels of the 16,966 in the Chinese DWF fleet. Krakken® lists 2,228 firms that own and/or operate these 6,122 vessels. Most firms own or operate a small number of vessels each. A total of 1,631 owners and/or operators (72.3% of these firms) possess and/or operate just a single vessel, and over half (57.8%)

⁷ Some requirements of the PSMA are included as membership obligations of certain RFMOs. For example, member states of the Indian Ocean Tuna Commission are bound by Resolution 16/11 on PSMA.

Table 4 Distribution of owning and operating companies by fleet size

Vessel number range	Companies			Vessels		
	Total	Running total	Cumulative percentage	Total	Running total	Cumulative percentage
1	1,631	1,631	73.2%	1,631	1,631	26.6%
2–10	502	2,133	95.7%	1,909	3,540	57.8%
11–20	50	2,183	98.0%	722	4,262	69.6%
21–50	37	2,220	99.6%	1,060	5,322	86.9%
51–100	6	2,226	99.9%	415	5,737	93.7%
100+	2	2,228	100.0%	385	6,122	100.0%
Total	2,228			6,122		

Source: elaborated from FishSpektrum (2018).

of these vessels are owned and/or operated by the 95.7% of companies with fleets of 10 vessels or fewer (Table 4).

While our sample is not representative of the wider Chinese DWF fleet, these figures suggest that Mallory's (2013) assessment that 70% of Chinese DWF businesses are SMEs may be an underestimate. Alternatively, some of these small companies may be owned by larger conglomerations, with individual companies registered for each boat for tax or insurance purposes.

On the other hand, there is a relatively small number of very large companies that own or operate extensive fleets. The 10 largest firms own or operate 898 vessels (14.7% of these vessels) between them. Table 5 lists information on the largest six fleets. The largest fleet of 257 vessels is owned by the China National Fisheries Corporation (CNFC) (Box 2), while Poly Group Corp. (PGC) owns 128 (Box 3).

There is little publicly available information on the ownership of Chinese DWF vessels by companies. Efforts to cross-reference data from Krakken® with corporate websites and publicly available information suggests that patterns of ownership and operation are complex, but also perhaps more consolidated than appears when looking only at the names of registered owners. Aside from the 7.5% of vessels operated by companies other than their owners, many of the firms in our sample are subsidiaries within larger corporate frameworks.

For example, China National Fisheries Yantai Marine Fisheries Corp., for which we have

data on 66 vessels, is a subsidiary of the CNFC (FIS, 2019a). Krakken® also records seven vessels as owned by Zhoushan Marine Fisheries Co. Ltd, which may be the same as (CNFC) Zhoushan Marine Fisheries Co. Ltd, a subsidiary of CNFC according to FIS (2019b).

Similarly, Rongcheng Rong Yuan Fishery Co. Ltd (68 vessels) is a subsidiary of the Jinghai Group Co. Ltd which has a further six vessels

Table 5 Largest six Chinese fleets of distant-water fishing vessels

Name	Location	Owned/operated
China National (Overseas) Fisheries Corp. (CNFC) / Zhong Yu Global Seafood Corp. – 中国水产总公司 / 中渔环球海洋食品有限责任公司	Beijing	257
Poly Group Corp. / Poly Technologies Inc. / Fuzhou Hong Dong Yuan Yang Pelagic Fishery Co. Ltd – 宏东渔业股份有限公司 / 福州宏东远洋渔业有限公司	Beijing	128
Fujian Province Pingtan County Heng Li Fishery Co. Ltd – 福建省平潭县恒利渔业有限公司	Fuzhou, Fujian	86
Dalian Chang Hai Yuan Yang Pelagic Fishery Co. Ltd / Dalian Chang Hai Ocean Going Fisheries Co. Ltd – 大连长海远洋渔业有限公司	Zhong Shan, Dalian	76
Rongcheng Rong Yuan Fishery Co. Ltd – 荣成市荣远渔业有限公司	Shandong	68
China National Fisheries Yantai Marine Fisheries Corp. / Yantai Marine Fisheries Co. Ltd – 烟台海洋渔业有限公司 / 中国水产烟台海洋渔业公司	Shandong	66

Source: elaborated from FishSpektrum (2018).

Box 2 The Chinese National Fisheries Corporation

The CNFC was China's original state-owned DWF fleet, which set sail in 1985 with five vessels. By 1999, private vessels made up around 70% of the fleet, and CNFC owned 556 vessels (Mallory, 2013). With its subsidiaries, CNFC remains a publicly listed state company and China's largest DWF operation, with offices in Spain, Morocco, Guinea-Bissau, India, Yemen, Saudi Arabia, Hong Kong and Australia (FIS, 2019a). CNFC vessels catch tuna in the western central Pacific, squid in the southeast Atlantic (Harkell, 2019) and krill in the Antarctic (Liu and Brooks, 2018). Of the 257 CNFC DWF vessels we could identify in Krakken®, 192 are flagged to China, with the rest in Senegal (31), Mozambique (12), Mauritania (9), unknown (7), Belize (2) and 1 each in Comoros, Morocco, Panama and St Kitts and Nevis.

Box 3 Poly Group Corp.

Of the vessels in our sample, 128 are owned directly by PGC – a large corporation with wide-ranging interests across different sectors of China's economy, including defence manufacturing, real estate and engineering. PGC has been described as a commercial arm of the Chinese People's Liberation Army (Welker, 1997; Bickford, 1999; Busch, 2019). The corporation encompasses a wide network of subsidiaries and affiliates, the structures of which are difficult to establish. In 2010, PGC signed an agreement with Mauritania granting access for 50 vessels to Mauritanian marine resources for 25 years in exchange for \$100 million of investment (Transparent Sea, 2012). Of the 128 PGC vessels in our sample, 24 were flagged in Mauritania.

in the Krakken® database. The Jinghai Group's website mentions several other subsidiaries, including Shandong Shawodao Fishery Co. Ltd and Shandong Haiyu Ocean fishery Co. Ltd, for which we have no additional data (Jinghai Group, 2019).

4.4.2 International ownership and operation of China's DWF vessels

Krakken® lists 840 vessels owned and/or operated by 258 firms registered outside China. In Ghana, for example, 48 non-Chinese firms owned or operated 142 Chinese DWF vessels, while in Mauritania 23 companies owned or operated 122 Chinese DWF vessels. There are several plausible reasons why owners may choose to register ownership outside China and use non-Chinese operating firms. As mentioned in Section 4.3, countries such as Ghana reserve fishing rights in their EEZ to national firms; re-registering ownership of a vessel is one way to circumvent these regulations. As another example, we identified 26 vessels flagged by China, but with registered ownership in Spain. Of these, 24 are operated by firms registered in Guinea and the remaining two by the same Spanish company,⁸ perhaps to access EU fishing rights in Guinea's EEZ.

Another reason for international registration is to take advantage of preferential tax regimes.⁹ We found 41 vessels with owners or operators registered in countries commonly regarded as tax havens, including Fiji (21 vessels), Panama (9), Vanuatu (6 vessels), Seychelles (2), Trinidad and Tobago (2) and Samoa (1).

In some countries, Chinese DWF vessels are owned by different companies registered at the same street address or post-office (PO) box. For example, Krakken® contains details of: two companies owning or operating 258 vessels registered at the same Beijing address; two companies owning or operating 81 vessels registered at the same Cheng Shan (Shandong province) address; two companies owning or operating 52 vessels registered at the same Shanghai address; and, in Fiji, five companies owning or operating 25 vessels registered at

8 Dalian Lian Run Overseas Oceanic Pelagic Fisheries Co. Ltd – 大连连润远洋渔业有限公司 registered in Las Palmas, Spain.

9 Based on 'The Council conclusions on the revised EU list of non-cooperative jurisdictions for tax purposes', Council of the European Union, 2020 (www.consilium.europa.eu/media/42596/st06129-en20.pdf).

the same PO box. It is not clear what the legal relationships between these companies may be, if any; the address may be that of a lawyer or shipping agent acting on behalf of multiple companies. Several of these firms operate vessels owned by the others, further suggesting that actual distinctions between them may be blurred.

There are legitimate reasons for registering businesses in tax havens, and it is not unusual to register vessels in flag-of-convenience nations (Section 4.3). As a package, however, registering ownership in a tax haven that is also a flag of convenience offers the possibility of enabling the laundering of profits from illegal fishing (Blaha, 2018) and of hiding wealth from legal operations (Alstadsæter et al., 2018). Krakken® identifies 22 Chinese DWF vessels flagged to nations of convenience and with owners or operators registered in tax havens (15 companies). Of these, eight vessels flagged in Panama are owned by companies registered in Panama, and four vessels flagged in Vanuatu are owned by companies registered in Vanuatu. The others are all owned in one country and flagged in another.

A lack of transparency, labyrinthine corporate structures, and the complexity of a vessel's identity – in terms of flag state, operators and registered owners – can make it extremely challenging to identify who ultimately owns and benefits from vessels involved in DWF fishing. Using flags of convenience and shell companies in tax havens offers further opportunities for obscurity to those who might want it. While there can be legitimate reasons for engaging in these practices, they also shelter those engaged in transnational criminal activity, such as IUU fishing.

The proliferation of SMEs has already been recognised as a challenge to the Government of China's capability to control the Chinese DWF fleet effectively (Mallory, 2013). Our findings suggest that authorities can make significant impact by initially focusing efforts on a relatively small number of very large firms and their subsidiaries that control a large number of vessels, their agents, and the fisheries organisations where they work. That the largest companies are also state owned provides an opportunity for the authorities to demonstrate the Government of

China's commitment to setting standards and combatting IUU in the DWF fleet. Investigating the ultimate beneficiaries of vessels owned by companies registered in tax havens may also be of interest to the Chinese authorities.

4.5 At least 183 vessels in China's DWF fleet are suspected of involvement in IUU fishing

Krakken® lists 183 Chinese DWF vessels in connection with IUU fishing activities. This includes vessels appearing in public IUU registries, reports on suspected IUU vessels, and records of convictions for IUU fishing, including Macfadyen et al. (2019), the Environmental Justice Foundation (EJF 2018a; 2018b), Sea Shepherd (2017) and Greenpeace (Wheeler, 2017).

This does not imply that other Chinese DWF vessels we have identified are not involved in IUU activities. The involvement of China's DWF fleet with rule-breaking is undoubtedly more extensive. An investigation in Ghana, for example, found dozens of Chinese DWF vessels not listed in Krakken® engaged in IUU fishing (EJF, 2018a). However, Krakken® has records of just four Ghanaian-flagged Chinese DWF vessels suspected of involvement in IUU fishing. This gap implies that 183 is likely to be a significant under-representation the total number of Chinese DWF vessels involved in IUU fishing.

Of the 183 IUU Chinese DWF vessels identified in Krakken®, 89 are long-liners, and 58 are trawlers. This type distribution contrasts with Krakken's® baseline data for long-liners and trawlers in Chinese DWF fleet, where 38% are trawlers and 20.7% are long-liners. This may reflect more effective IUU listing processes among tuna RFMOs. The IUU list also contains 17 reefers, nine seiners, four squid-jiggers, three support vessels, one carrier, one multipurpose vessel and one pole-and-line vessel.

Compared to the baseline for China's DWF fleet, a relatively large proportion of these vessels are flagged overseas (100 vessels, 54.6%), to 18 non-Chinese nations. The most frequent non-Chinese flag nations are Fiji (40 vessels)

Table 6 Suspected illegal, unreported and unregulated fishing vessels per country flag

Flag	Number
China	83
Fiji	40
Senegal	13
Panama	8
Kiribati	8
St Vincent and the Grenadines	7
Sierra Leone	4
Ghana	4
Papua New Guinea	3
Vanuatu	2
Honduras	2
Russian Federation	2
Belize	1
Equatorial Guinea	1
Liberia	1
Marshall Islands	1
Democratic People's Republic of Korea	1
Philippines	1
Marshall Islands	1

Source: elaborated from FishSpektrum (2018).

and Senegal (13 vessels) (Table 6). Flag-of-convenience nations account for 24 vessels,¹⁰ with Panama (8) and St Vincent and the Grenadines (7) the most common.

There are 50 vessels owned by companies registered in recognised tax havens, with 40 in Fiji, eight in Panama and two in Vanuatu. This may imply that many of these vessels are engaging in IUU opportunistically, and that – at least in terms of IUU activities – reflagging and foreign registration of companies is related more to proximity of and access to resources than to permissive standards and enforcement of the flagging state. The high proportion of vessels registered in Fiji may well represent an

above-average detection rate, rather than a unique concentration of IUU activity.

By cross-referencing the lists of IUU vessels with Krakken®'s records on operators, several companies emerge as repeat suspects and offenders. Just 10 companies own 46% of the suspect vessels. The CNFC owns and operates 15 vessels. The Dalian Lian Run Overseas Pelagic Fisheries Co. owns 15 vessels operated by five different firms registered in Guinea. The Sunshine Fisheries Co. operates seven vessels in Fiji, and shares the same Fijian PO box number with three companies that operate four further vessels owned by Sunshine. The Zhonshui Ocean Shipping Corp. owns eight, and Hangton Pacific, based in Fiji, owns seven. Two other firms own 13 vessels operated by five firms registered in Guinea.

This implies that, to tackle large companies that are repeat offenders, the Chinese authorities may be able to focus their enforcement efforts efficiently. That CNFC is a state company also presents an opportunity for the Chinese authorities to lead by example.

However, monitoring foreign-flagged Chinese-owned vessels presents Chinese authorities with a different challenge. When China is not the flag state, China's responsibility for these vessels is moral rather than legal. Simply providing information on vessels suspected of IUU fishing to developing-country governments is unlikely to result in action. Even when aware of violations, many nations in West Africa do not have the equipment and personnel to enforce the law effectively, and find limited support from fisheries powers to upgrade enforcement capacity (Daniels, 2019).

The Chinese authorities' ability to monitor and enforce foreign-flagged Chinese vessels is limited, as this may constitute interfering with flag-state operations. However, where Chinese agencies have no authority to inspect Chinese vessels flying foreign flags in foreign waters, there are options for China to support local enforcement through technical assistance and capacity-building.

¹⁰ Panama (8), St Vincent and the Grenadines (7), Honduras and Vanuatu (2 each), Belize, Democratic People's Republic of Korea, Equatorial Guinea, Liberia and Marshall Islands (1 each).

5 Analysis: development implications

5.1 The scale, scope and impact of China's DWF fleet and activities

Our results suggest that the scale, scope and impact of China's DWF activities are significantly larger than has been previously understood. At 16,966 vessels, we estimate that the Chinese DWF fleet is 5–8 times larger than previous studies suggest. The Chinese government has not revealed the size and composition of its DWF fleet but it did, in 2017, announce plans to restrict the size of this fleet to 3,000 vessels by 2020. This stated ambition suggests that the government recognises figures that are similar to those in previous studies.

As discussed in Section 4.2, one possible reason for such a large discrepancy in DWF fleet numbers may be that China does not consider fishing activity outside its EEZ but within disputed areas of the Yellow, South and East China Seas as DWF fishing (Zhang, 2015: 8). If so, our findings suggest that researchers using data from the government to analyse China's DWF fleet should treat that data with additional caution.

Although we have no evidence on catch data, our findings clearly imply that China's DWF fleet is exerting greater pressure on global fish stocks than is currently recognised. The greenhouse gas emissions and other adverse environmental impacts of China's DWF fleet activities – such as levels of waste, oil spills and pollution – are also likely to be higher than currently understood. Recent research has shown that China subsidises fishing through tax exemptions, particularly on fuel, to the value of \$16.5 billion per year, or 47% of total global fishing subsidies (Arthur et al., 2019). Our findings suggest the extent to which these incentives have enabled DWF

operations. Our findings also indicate that a large proportion of these vessels are active in the Northwest Pacific region, and that the Southeast Pacific and Southwest Atlantic are regions with a high intensity of fishing activity, where China's DWF fleet may be having the most significant environmental impacts.

The relatively high proportion of trawlers in several of our subsamples is another cause for concern, given the high level of ecological damage associated with bottom-trawling. Indeed, China has announced plans to restrict the production of new trawlers and increase regulation of trawling within its EEZ (Zhang, 2015; Jiang et al., 2018). Yet China's DWF fleet contains an unusually high proportion of trawlers. For example, of the 518 Chinese DWF vessels flagged in African countries, 82% are trawlers (Section 4.3). This implies a significant export of ecological risk to developing-country waters, despite increasing regulation and restrictions on trawling in countries where these vessels are registered, including Ghana and Mauritania (Republic of Ghana, 2002; Tavares, 2003; McConnaughey et al., 2019). Box 4 gives more information on the situation in Ghana.

In recent years, the Government of China has become more sensitive to national and international debates about environmental issues, and mounting domestic concerns over food safety (Godfrey, 2019a). In particular, China has become more sensitive to accusations that it is contributing to the collapse of global fish stocks, and has acknowledged the need to restrict the size and operations of the DWF fleet.

The 13th Five-Year Plan for National Ocean Fisheries Development (MARA, 2017) made commitments to improve regulation of the

Box 4 China's distant-water fishing in Ghana

With 137 ships, Ghana has the largest registry of Chinese DWF vessels outside China; 121 of these are trawlers. More than a quarter of those on our list of Chinese DWF vessels that are flagged to African countries fly the Ghanaian flag. Marine resources are important to livelihoods and food security in Ghana, and over two million people depend directly or indirectly on marine fisheries for income and employment (FAO, 2016b). However, the country's rich fishing grounds have come under increasing pressure from industrial fishing, particularly from DWF vessels from China and elsewhere. The incomes of local artisanal fishers have fallen by around 40% since the turn of the century, reflecting greater competition with industrial vessels for increasingly scarce resources (Republic of Ghana, 2016).

In 2014, a total of 107 industrial trawlers were reported to be operating in Ghanaian waters (EJF, 2018a). Some experts regarded this as well above pressure the fishery could sustain, and industrial fishing was directly linked to overfishing of Ghanaian waters where key species like sardinella, a crucial source of protein for people living in coastal communities, are on the brink of collapse (Lazar et al., 2018).

Ghana has taken steps to regulate industrial fishing, and to ensure that it returns more benefit to Ghana's economy. Ghana's Fisheries Act of 2002 limits fishing licences for semi-industrial and industrial fishing vessels to those flying a Ghanaian flag. Licences – with the exception of those for tuna vessels – must also be entirely owned by Ghanaian companies (Republic of Ghana, 2002). Ghana's 2015–2019 National Fisheries Management Plan also set out to reduce fishing days for the industrial trawl fleet by 50% by 2018 (Republic of Ghana, 2015).

A 2018 report by the Environmental Justice Foundation alleges that Chinese DWF firms use Ghanaian 'front companies' to circumvent these regulations. Registering Ghanaian subsidiaries and working with Ghanaian operations firms, Chinese businesses import their vessels and secure licences. However, the vessels remain 'almost exclusively' operated by Chinese firms (EJF, 2018a).

For example, the EFJ report concludes that the Chinese company Rongcheng Marine Fishery Co. Ltd (RCMF) operates 15 Ghanaian-flagged trawlers (EJF, 2018a). Krakken® lists these vessels and 10 further Ghanaian-flagged RCMF-owned ships. These are the *Lu Rong Yuan Yu* 219, 926, 927, 928, 929, 956, 959, 981, 982 and 988. Collectively, these 25 vessels represent almost a fifth of all the Ghanaian-flagged Chinese DWF vessels we have identified.

The 137 vessels we have identified as Ghanaian-flagged Chinese DWF vessels support the EJF's claim. All of these vessels were constructed in China, previously flagged in China, and/or have Chinese names such as *Dalian*, *Guo Jin*, *Lian Run*, and *Zhong Yuan Yu*. Most of the vessels we identify are both owned and operated by Ghanaian-registered firms. Five vessels appear to be in breach of the 2002 Fisheries Act: four trawlers (*Zhong Lu Yu* 1003 and 1004, and *Lian Run* 29 and 30) are owned by Chinese firms, two of which are operated by Ghanaian firms, and the fifth (*Lian Run* 14) is a trawler owned and operated by a Spanish company. Two further Chinese-owned and operated vessels are listed as pole-and-line fishers rather than trawlers, and may well be hunting tuna within the rules of the 2002 Fisheries Act.

DWF fleet. Alongside measures to encourage consolidation and streamlining of fleet ownership, the plan committed to tackling IUU fishing by establishing a blacklist, improving monitoring, increasing inspections on the high seas, and implementing the PSMA. Other commitments include requiring DWF vessels to

register with authorities, reviewing regulations governing overseas fishing, and cutting fuel subsidies underpinning DWF operations by 60% (Jacobs, 2017; Godfrey, 2019b).

In February 2018, a Ministerial Circular reported that 264 vessels from 78 'offshore fishing enterprises' had been punished for

violations in 2017, and that 15 company officials and fisheries employees had been added to a blacklist (MARA, 2018). Punishments included loss of a year's fuel subsidies, and suspension of fishing licences and enterprise qualifications. Included on the list were vessels found guilty of: illegal fisheries transshipments at sea, using illegal gear, illegal operations in foreign waters, fishing in protected areas, misreporting catches, and health and safety violations. Among others, the Dalian Lian Run Ocean Fishery Co. Ltd.'s DWF certificate – for an enterprise with 28 vessels recorded in Krakken® – was revoked for IUU violations in Ghana (see Box 4) after being reported by Greenpeace (Greenpeace, 2018).

A revised Fisheries Law regulating China's fishing industry is also expected to come into force later in 2020. This would increase penalties for IUU fishing, restrict reflagging of vessels, require registration of port movements and develop a blacklist system (Godfrey, 2019b; Chun, 2020). Also, the central government is expected to introduce measures to strengthen monitoring of China's DWF fleet, with punishments for any vessel that removes or turns off its vessel-monitoring system (Chun, 2020).

However, meeting these commitments is likely to be a challenge, requiring significant institutional development and reform to implement policies and enforce them effectively (Chun, 2020). It is also not clear whether the efforts reported in the 2018 Circular have persisted; we found no similar reports of IUU enforcement during 2018 or 2019. According to Godfrey (2019a), most central government action to date has concentrated on tackling illegal aquaculture ponds and fishing within China, rather than tackling the DWF fleet.

Even achieving the ambitious goals for the DWF fleet may not go far enough. Reducing fuel subsidies by 60% would still leave China with the highest level of harmful fishing subsidies in the world (Arthur et al., 2019). The Environmental Justice Foundation has challenged the Government of China to improve transparency of its DWF fleet operations, especially by making data more robust and accessible (EJF, 2018a). DWF fisheries and business interests have considerable political and economic weight in China; our findings suggest

that the scale of these interests may have been underestimated by previous studies.

The Government of China itself may not be fully aware of the scale of the governance challenge it faces. Incomplete data on a large, complex and fragmented fisheries sector makes monitoring and enforcement a challenge for all parties. There are additional policy challenges posed by the different interest groups in the fishing sector. One challenge is the proliferation of many small owning and operating companies (approximately 75% of all companies). Even if these are ultimately owned by larger conglomerates, effectively regulating a large number of small companies with limited capacity presents certain logistical and information challenges.

By contrast, our evidence suggests that a large number – perhaps even the majority – of DWF vessels are owned by a relatively small number of companies, with state-owned corporations chief among them. Focusing enforcement efforts on these companies may be an effective means of reaching a large proportion of the fleet. The revocation of the DWF licence of the Dalian Lian Run Ocean Fishery Co. Ltd in 2018 shows that the Chinese authorities have been willing to take such measures in the past. Focusing on IUU activities by larger public and semi-public enterprises is an opportunity for regulatory authorities to demonstrate the state's willingness to lead by example.

5.2 China's DWF activities in a development context

Our findings suggest that the negative impacts of China's DWF fleet on developing countries is more significant than has been realised to date. These concerns arise partly from reports about the arrival of large numbers of industrial vessels that compete with local fishers, asset-strip natural resource bases and undermine local environmental security, food security and livelihoods (Clover, 2016; Daniels, 2018).

Many of the agreements governing Chinese DWF in developing countries' waters are framed in terms of economic development. Chinese vessels gain access to marine resources in exchange for inward investment, industrial

development and the generation of exports for the host country (Dahir, 2018; Mallory, 2012; Transparent Sea, 2012). However, in practice these deals are often poorly structured for the host nation. Deals may see more catch licensed than stocks can stand, local fishers lose income and local governments can lose tax revenue if landings and catches are not appropriately measured (Clover, 2016).

Based on the review of several studies, Mallory concluded in 2012 concerning China that ‘fisheries access agreements, on the whole, have led to unsustainable use of fisheries resources and have negatively impacted the socioeconomic development of host countries’ (Mallory, 2012). A case study in Mauritania, for example, found that, although a fishing deal with PGC offered to create 2,463 jobs for Mauritians, job losses in traditional fishing totalled 13,000 during 2014 alone, at least partly caused by competition from foreign industrial vessels (Sherpa, 2014).

Our findings suggest that Chinese DWF activities may have greater impacts in developing countries than is currently understood. The number of vessels active in the Northwest Pacific region underlines the conflicts reported by fishers from Viet Nam, the Philippines and Cambodia (Fache and Pauwels, 2016; Meick et al., 2018; Wesley-Smith and Potter, 2010). Widespread trawling behaviour, particularly off Africa, and intense squid-jigging off the coasts of South America all imply competition with fishers from other countries.

5.3 IUU fishing and its governance

Our findings provide new evidence on the scale of Chinese interests in IUU fishing activities. In total, we identified 183 Chinese vessels in Krakken® that were either suspected or confirmed to be involved with IUU fishing. To give some context, the largest list of global IUU vessels – aggregated from RFMOs and INTERPOL – lists a total of 311 vessels (Trygg Mat Tracking, 2020). China’s role in IUU fishing is, therefore, clearly significant. The IUU vessels we have identified include vessels owned by some

of China’s largest, state-owned DWF companies, as well as 104 vessels flagged outside China.

Chinese engagement in IUU activities is most probably more extensive, and Krakken®’s dataset on IUU fishing is not exhaustive. Several of the companies covered in our analysis have vessels allegedly engaging in IUU activities not recorded in Krakken®. For instance, in 2016, the Argentinian coastguard sank a vessel owned by the CNFC, for allegedly fishing illegally in its territorial waters (CNN, 2016). At least 15 other vessels from this corporation are listed in Krakken® as suspected or convicted of IUU practices in different episodes.¹¹ The scale and extensive global operations of China’s DWF fleet poses a significant challenge to those engaged in combatting IUU fishing.

Our identification of 927 Chinese-owned, foreign-flagged vessels highlights a further obstacle for enforcement. Under international law, China is not responsible for the standards under which these vessels operate. Nor, in principle, can Chinese authorities inspect foreign-flagged vessels in foreign waters without the cooperation of the host nation, even if those vessels are ultimately owned by Chinese businesses. Yet many developing coastal states lack the equipment and other resources required for investigation and enforcement at sea. As a result, many of these vessels are able to operate without close surveillance. Expanding its activities in fisheries technical cooperation to include capacity-building for enforcement would demonstrate China’s commitment to the good governance of its corporations’ behaviour overseas.

Other advanced economies can also help to improve maritime law-enforcement capacity in coastal developing states and flag states, and to improve enforcement cooperation between flag, coastal and port states. For example, EU regulations require fish imports to be accompanied by-catch certificates issued by the flag state.

However, it is not only foreign-flagged vessels that are at fault. Almost half the 183 IUU suspects we identified were flagged in China.

11 The vessels *North Ocean*, *West Ocean*, *Shun Chang* No. 2 and *Soleil* Nos. 7, 8, 9, 10, 11, 12, 51, 61, 65, 66, 67 and 68.

As we have already discussed, the Chinese authorities face considerable challenges with enforcing – and gaining compliance with – existing policies and regulations. China is ranked as the worst-performing nation on the IUU Fishing Index, which looks at coastal, flag and port state responsibilities, among other indicators (Macfadyen et al., 2019). The size and extent of the Chinese fleet’s activities around the world make this task even more daunting for China’s authorities.

Some companies, including the CNFC and PGC, appear to be repeat IUU offenders. Large-scale, repeat offenders are obvious targets for the focus of enforcement agencies. As such offenders are also often either state-owned or linked to the state, focusing on them also provides the authorities with the opportunity to establish their credibility as enforcement agencies – and to demonstrate the depth of China’s commitment and leadership on this issue. China can support international enforcement efforts by improving

the transparency of its registry, particularly by listing the ultimate owners of vessels rather than just the name of the immediate company (which is often a subsidiary).

This is an issue for action by not only Chinese and developing-country authorities. Krakken® records show that 32 of the vessels we have identified as IUU vessels remain registered with the European Commission’s Directorate General for Health and Consumer Protection (DG SANCO), despite their involvement with IUU fishing. This means that they are allowed to continue exporting to the EU. Of these 32 vessels, 15 belong to Dalian Lian Run Overseas Oceanic Pelagic Fisheries Co. Ltd., 11 to CNFC subsidiary Zhong Yu Global Seafood Corps and two to Ocean Harvest (Fiji) Ltd. The DG SANCO should be more proactive about de-listing suspect vessels. This also demonstrates the generally poor coordination between IUU registries and investigations and the bodies responsible for maintaining standards and enforcement.

6 Conclusions and key policy recommendations

6.1 Conclusions

The cultural, economic and political importance of the fisheries sector in China, booming economic growth and demand for fish protein, and the strategic policy of ‘going out’ has created the conditions for an extraordinary boom in China’s DWF activities. The fleet has grown from 13 vessels in the mid-1980s to as many as 16,966 vessels today, operating all over the world. The number of SMEs engaged in DWF has proliferated, and the structures and tax affairs of large corporate fleets are now managed with much greater sophistication.

This boom has benefited China, Chinese consumers and Chinese business. However, the majority of social, environmental and economic costs have been borne by developing coastal states, who have not shared equally in the benefits.

The rapid growth of China’s DWF has not been matched by capacity of the Chinese state to govern its operations. China has not acceded to a range of pertinent international agreements, and does not require high standards from its registered vessels. As a consequence, Chinese DWF companies are left to police themselves and negotiate access to the fisheries resources of developing coastal states. This contrasts with the EU’s policy of reducing its fishing fleet and exerting greater control over its global operations. The Chinese DWF vessels are often shielded from public scrutiny, and frequently take advantage of weak regulatory and governance structures in the regions where they operate.

The Chinese DWF is not solely responsible for the global fisheries crisis. Other fleets are also responsible for overfishing, and many governments in developing countries are either

unable or unwilling to monitor their waters.

Collectively, the international community has failed to establish global, centralised databases of DWF or IUU vessels. IUU fishing has still not been declared as a transnational crime.

However, China is the world’s largest exporter and consumer of fishing products, and has the world’s largest DWF fleet. Its authorities have an interest in leading the fight against overfishing and IUU fishing globally, and in managing effectively the operations of its massive DWF fleet. This is not yet happening. This inaction has led some to criticise the Government of China’s efforts to regulate fishing in domestic waters as playing the role of ‘an environmentalist at home while plundering abroad’ (Godfrey, 2018; 2019a).

The Chinese government may be increasingly sensitive to international concerns about the expansion and behaviour of its DWF fleet. In 2017, it announced plans to restrict the number of DWF vessels to 3,000 by the year 2020. An announced review of the Administration of Offshore Fisheries, which regulates overseas fishing, is expected to set higher fines and constrain the reflagging of vessels (Godfrey, 2019b).

However, the central government faces opposition from provinces reluctant to lose the economic boost provided by the DWF fleet. Both Fujian and Shandong, for example, have ambitiously expanded their DWF fleets over the last five years (Kang, 2016). Proposals are afoot to devolve responsibility for fisheries-sector development to regional governments. This would make the central government’s intention of reducing the number of vessels and addressing the drivers of expansion – including cutting subsidies – much more challenging (Kang, 2016).

Our research findings suggest that the Government of China's goal in limiting the DWF sector to just 3,000 vessels and exerting tighter control over its operations will be even more difficult to achieve than has been previously recognised. The scale of the DWF fleet, its complex global operations and business structures, and the lack of coherent, transparent data, are all major challenges. Achieving that goal will require systematic reform of the DWF sector and its governing institutions.

6.2 Key policy recommendations

6.2.1 Government of China

Our findings suggest that the scale of the task China faces in meeting its goal to reduce its DWF fleet to 3,000 vessels is greater than previously realised. Our findings also concur with those of other researchers, who have identified significant gaps in China's capacity for governing its DWF. China can take the following significant steps to demonstrate global leadership on the governance of DWF, sustainability of global fisheries and combatting IUU:

- requiring all DWF vessels to enter a centralised, publicly and internationally accessible registry, including details on holding companies as well as immediate subsidiary owners;
- adopting higher standards as a flag state with obligations for its DWF fleet, including signing, ratifying and implementing the PSMA, and joining all appropriate RFMOs and enforcing compliance with their obligations;
- targeting monitoring, compliance and enforcement efforts on larger, particularly state-owned, companies with the most extensive DWF operations;
- strengthening bilateral cooperation and capacity-building for fisheries enforcement in coastal developing states where the Chinese DWF is active;
- enforcing regulations on bottom-trawling within China's EEZ and in waters claimed by China in the Yellow, South and East China Seas;
- introducing disincentives for bottom-trawling on all Chinese-flagged vessels.

6.2.2 Coastal developing-country states

Coastal developing states can support global efforts to combat IUU fishing and enhance the governance of DWF fleets by:

- enforcing existing regulations on registration and tackling 'phony flagging' of DWF vessels;
- making all international fisheries agreements, including those with China's DWF, publicly available;
- signing, ratifying and implementing the PSMA designed to tackle global IUU fishing.

6.2.3 International bodies and agencies

Global governance of DWF and IUU activities needs more effective regional and global capacity. RFMOs, national governments, multilateral agencies and international development donors, can contribute by:

- monitoring, information-sharing and prosecution of vessels and companies suspected of IUU activities;
- monitoring the presence and activities of Chinese fishing vessels outside China's EEZ in the Yellow, South and East China Seas;
- taking proactive measures to de-list IUU vessels and companies from import/export agreements;
- supporting coastal developing states to combat IUU activities in their own waters.

6.2.4 Researchers

Our findings contribute to global work on the scale, impacts and governance of China's DWF. Suggestions for future research include:

- more research and analysis on China's fleet to refine estimates of the scale, extent and activities of China's DWF;
- research on the ecological, social and economic impacts of China's DWF fleet, particularly in the Northwest Pacific, Western Central Pacific, Southeast Pacific and Southwest Atlantic regions and in West Africa;
- more research on the activities of transnational companies engaged in DWF, particularly those operating in flag-of-convenience states and tax havens;
- extending the methods employed in this paper to the DWF fleets of other nations, and over longer timeframes.

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Annex 1 Methodology

Our study combines big data analytic techniques, ensemble algorithms and GIS. The methodology involves both dynamic (tracking) data and static (descriptive) data.

A1.1 Dynamic data

We obtained dynamic data from Vulcan's Skylight for 2017 and 2018 (24 months). Using the AIS data from the vessels in our database, we were able to visualise the positions and behaviour of possible fishing vessels for those cases with sufficient data density. Using GIS software, we extracted metadata from these time series to visualise the Chinese DWF vessels' operations and movements, based on their geographic location and other information, including the depth in which they operated (using bathymetry maps) and geographic information of fishing areas provided by the UN FAO.

A1.2 Static data

We obtained static data for this study from the November 2018 version of the FishSpektrum Krakken® database (FishSpektrum, 2018). Krakken® is the world's largest database on fishing vessels, using unique vessel identifiers (UVIs). Krakken® accounts for some 1.5 million historical references representing more than 800,000 vessels, offering more than 100 specific information items per vessel, with historical data going back to 2009.

We performed 10 rounds of extractions to mine the data on every Chinese vessel in Krakken® capable of DWF. Specifically, we extracted data on vessels that: have been registered with a unique IMO number; are registered with a RFMO; have an MMSI number shown to be active outside the Chinese EEZ during 2018; have been inspected by the Chinese Fisheries Authorities in waters of a country other than China; are registered as exported or impounded by the Chinese customs during 2018; or are registered with China's Distant Water Fisheries Association and are therefore able to operate abroad. Chinese names in Krakken® follow a coherent transcription system and have either a unique IMO number or other identification numbers employed to identify them to avoid duplication.

We consider the Chinese DWF fleet to be composed of the aggregate of groups formed by data Extractions 1, 2, 3, 4 and 6 of the 10 rounds of data extractions from the Krakken® database. Table A1 shows the inclusion criteria for all Chinese DWF vessels that we have used in all the extractions. In the extractions, we consider that a current or previous Chinese name, operator or beneficial owner is an indication of Chinese interest. We have included all vessels in Krakken® that show traces of a Chinese interest.

To describe the Chinese DWF fleet, we examined the vessels': flags; IMO numbers; names; RFMOs they are registered in; year and place of construction; primary and secondary gear (e.g. trawler net); type of vessel (e.g. trawler); tonnage (e.g. ton gross tonnage); length, breadth and draught; engine power; fish-hull volume; status (e.g. sold or renamed); owner and operator and their addresses; AIS type (e.g. cargo, trawler); and IUU fishing metadata. We disregarded the information on vessel monitoring system (VMS) and communication system aboard as not relevant or redundant. We discarded any data marked as 'unreliable' in Krakken®.

A1.2.1 Extractions from the Krakken® database

The first group includes all vessels flagged to China with an IMO number. We assume that Chinese ship owners and operators that register their vessels with a unique IMO number intend to operate them in distant waters at some point. We discarded vessels with invalid IMO numbers (e.g. numbers that do not include the three letters ‘IMO’ followed by seven digits, of which the latter is a validation number).¹²

The second group includes all vessels flagged to China with no IMO number but registered with an RFMO. We assume that Chinese ship owners and operators that register their vessels with an RFMO intend to operate them outside China’s EEZ. However, some of them do not have an IMO number but operate within an RFMO. It is not clear why these vessels are not registered with an IMO number, since they can operate in the RFMO’s designated areas outside the Chinese EEZ.

The third group includes all vessels flagged to China with no IMO number and registered in no RFMO, but with an MMSI number, which have shown to be active outside the Chinese EEZ during 2018. We requested AIS positions of these vessels (amounting about 100,000 MMSI numbers) from the Krakken® database to find those operating outside Chinese waters in 2018.

The fourth group (gathering Extractions 4.1, 4.2 and 4.3) includes vessels with an IMO number but not currently flagged to China. We consider that these are industrial vessels because they are registered at IMO. They are divided into those: built in China (4.1); not built in China and previously flagged to China (4.2); not built in China, never flagged to China but related to Chinese interests (4.3). Vessels that include only Chinese characters are not easily bought by non-Chinese companies, according to sources from the industry.

The fifth group consists of non-Chinese reefers or large processing and fish-cargo vessels for validation purposes. These vessels are not part of the Chinese DWF fleet.

The sixth group (gathering Extractions 6.1, 6.2, 6.3 and 6.4) includes vessels without an IMO number, which are not part of any of the previous extraction groups. This group includes vessels: never flagged to China but showing Chinese interests (6.1); flagged to China and inspected by the Chinese Fisheries Authorities (CFAs) in waters of a country other than China (6.2); flagged to China and

Table A1 Criteria for extractions from the Krakken® database

Extraction	Criteria										Total
	Currently flagged to CHN	Previously flagged to CHN	IMO	RFMO	MMSI	Built in CHN	Chinese interests	CFA	CC	CNDWF	
1	YES	N/A	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,076
2	YES	N/A	NO	YES	N/A	N/A	N/A	N/A	N/A	N/A	575
3	YES	N/A	NO	NO	YES	N/A	N/A	N/A	N/A	N/A	12,490
4.1	NO	N/A	YES	N/A	N/A	YES	N/A	N/A	N/A	N/A	431
4.2	NO	YES	YES	N/A	N/A	NO	N/A	N/A	N/A	N/A	92
4.3	NO	NO	YES	N/A	N/A	NO	YES	N/A	N/A	N/A	86
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–
6.1	NO	N/A	N/A	N/A	N/A	N/A	YES	N/A	N/A	N/A	318
6.2	YES	N/A	N/A	N/A	N/A	N/A	N/A	YES	N/A	N/A	379
6.3	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A	YES	N/A	82
6.4	YES	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	YES	437
Total											16,966

Notes: N/A, not applicable due to being outside the criteria for this extraction; CHN, China.

Source: elaboration on information from the Krakken® database.

¹² The reliability of an IMO number can be confirmed using its check digit, which is the rightmost digit. This is done ‘by multiplying each of the leftmost six digits by a factor corresponding to their position from right to left, and adding those products together; the rightmost digit of this sum is the check digit’ (Port Klang Net Technical Working Committee, 2019).

registered as exported or impounded by the Chinese customs (CC) during 2018 (6.3); flagged to China and registered with China's Distant Water Fisheries Association (known as CNDWF) (6.4).

We then filtered the vessels in each extraction according to their last known status in Krakken®. We removed 177 vessels recorded as 'laid-up, scrapped, lost, sunk or decommissioned' and one vessel recorded as a 'cancelled order'. This left only the 16,966 vessels last recorded as 'active'.

A1.2.2 Algorithmic methods

We initially applied several learning models with associated learning algorithms that analyse data for classification and regression analysis. However, we decided that random decision forests are the most appropriate method here. Random decision forests are an ensemble learning method using decision trees to improve machine learning results by combining multiple models. Machine learning is an approach to data analysis that automates the development of analytical models, using software to explore data and identify patterns (Cukier, 2014; Marr, 2018).

To create automatic models able to detect fishing manoeuvres, we first examined a random selection of boats for each manoeuvre. Following the manoeuvre descriptions (detailed in Annex 2), the manoeuvres were identified and labelled by a fisheries expert. We used 500 models for each fishing manoeuvre: trawling, long-lining, squid-jigging and trap-setting. We used machine-learning approaches to examine and classify patterns of fishing behaviour.

We pre-processed data to avoid drawbacks that can arise during the early, training phase of modelling. Overfitting, for example, is the generation of a model that corresponds too closely or exactly to a particular set of data, and may therefore fail to fit additional data or predict future observations reliably. Overfitting can result in a model that learns about fishing areas or fishing schedules instead of the manoeuvres themselves – predicting that every boat crossing through an area frequented by trawlers is also a trawler, for example. The model could also wrongly learn that trawling manoeuvres are more likely to happen following the north–south axis, if training examples perform every manoeuvre oriented that way.

To avoid these drawbacks, our dataset had to be independent of position, time and orientation. We transformed: position information into distance travelled between two consecutive points, date information into time elapsed between consecutive points, and orientation information into change of boat orientation between consecutive points. These transformations result in variables that contain valuable information, from which we can infer what manoeuvre is being performed, while avoiding overfitting.

After this preprocessing phase, we used labelled manoeuvres to train a random forest algorithm composed of 500 decision trees for each specific manoeuvre. This resulted in a group of automatic labellers that we later used to provide fishing information for some of the studies in this report. To determine whether one AIS data point belongs to a fishing manoeuvre, we considered not only the particular information of the point but also a window of previous and subsequent data points that varies depending on the type of manoeuvre.

To validate the functional generalisation capabilities of the algorithm – that is, the opposite of overfitting – we tested the models with a selection of boats that were not involved in the training process. The ensemble algorithm and the preprocessing algorithms will be provided to authorities in developing countries with limited monitoring and enforcement capabilities, and that are interested in understanding the operations of foreign vessels in their waters.

Looking at the ship tracks on a map, a fisheries expert identified whether each ship was in transit (going straight from point A to B at a constant speed) or fishing. If the ship was fishing, the expert determined whether it was trawling (dragging a conical net), long-lining (hauling a line with baited hooks), purse-seining (creating a round net cage around the fish) or engaged in other types of fishing. Annex 2 describes these manoeuvres in more detail, and includes information on speed, duration and depth for different fishing manoeuvres.

Our model labels positions that are part of a fishing manoeuvre with a confidence percentage ranging from 0 to 1. For this paper, we created a score to understand the Chinese DWF's fishing activity: each time a vessel's position is labelled as being part of a trawling, long-lining, squid-jigging or trap-setting operation, with confidence greater than or equal to 0.75, it scores 1 point. Scores are spread over time in slots of one whole hour. Thus, a vessel's score in a time slot tells us how many positions have been labelled as being part of a particular fishing technique in that slot.

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Annex 2 Taxonomy of operations at sea

This taxonomy is offered as a tool for further studies and policy-making. We used it in this study to develop ensemble learning algorithms to identify how vessels operate and to identify common fishing manoeuvres. A vessel's speed and pattern of movement can indicate its activity. Speed is especially significant, as most of the methods to discriminate between fishing and non-fishing motion depend on the analysis of speed profiles (Bez et al., 2011). This can be based on either statistical and data approaches or expert knowledge. To increase accuracy, this study incorporates other indicators, including: spatial-temporal movement patterns, bathymetric charts, on-board gear, identification of the type of vessel and pictures of individual vessels.

A2.1 Trawling

Trawling involves dragging a fishing net through water. Trawlers range from small, undecked boats, powered by outboard engines, to factory trawlers of up to 3,000 gross tonnage, with up to 8,000 horsepower engines (Pusceddu et al., 2014; FAO, 2018a). Trawling can involve one or more ships working cooperatively, known as pair-trawling.

Speed: Trawling should happen at constant speeds of 1–7 knots, and usually 3–5 knots¹³ (FAO, 2018b; de Souza et al., 2016). This is to maintain vessel alignment in pair trawling. Speed depends on the catch species: from 1.5–2 knots for shrimp and small bottom-dwelling species, to about 5 knots for mid-sized pelagic fish (FAO, 2018b).

Depth: Efficient trawling takes place at a constant depth or pressure. This is why we used bathymetric charts showing submerged terrain in this study, to analyse trawling operations. Bottom trawlers typically work along a chasm, where there is high biodiversity because of temperature differences, following fish banks and tracing courses that look straight and parallel (Figure A1). Data cannot distinguish between bottom or mid-water trawling.

Duration: The duration of a tow depends on the outline of the sea bottom, the slope in the fishing area and the likely concentration of fish. It can last from 10–15 minutes to 10–12 hours, with around 3–5 hours most common (FAO, 2018b).

A2.2 Seine-fishing

Seine-fishing (or seine-haul fishing) uses a net called a seine that dangles vertically in the water. The bottom edge, or lead-line, is held down by weights and the top edge is buoyed by floats (FAO, 2018b; Stündl, 2013).

Speed: Vessels involved in seine-fishing show different speed patterns depending on the length of the net, the diameter of the circle that the vessel draws, the species and the time taken to draw a ring.

Duration: Half an hour for a school of about 100 metric tonnes of Bluefin tuna, for example, according to industry experts consulted for this report.

13 A knot is a speed of 1 nautical mile per hour or 1.852 kilometres per hour.

Depth: 200 to 300 metres.

Types: Seiners employ two main types of net: purse seines and Danish seines. A Danish seine (or anchor seine) is a conical net with two long wings with a bag where the fish collect. It is similar to a small trawl net. A purse seine's lead-line is held by purse rings hanging from the lower edge of the gear; a purse line drawn through the rings gathers the net to contain the fish (FAO, 2018a). This is the most efficient gear for catching large and small pelagic species that shoal, such as tuna.

The authors could not identify any purse-seining by the Chinese fleet; only 7.3% of the Chinese DWF fleet are seiners.

A2.3 Long-lining

Long-lining vessels launch a series of long fishing lines fitted with hundreds or thousands of baited hooks (FAO, 2018b; Stündl, 2013). The number of lines depends on the size of the ship, the number of crew members and the kind of mechanisation and automation available on the ship. Long-lines can be left drifting for pelagic fishing or set on the bottom for bottom species, or maintained at a certain depth by regularly spaced floats.

Speed: A constant 4–6 knots, depending on the crew (both setting and gathering the line).

Duration: When the last hook is in the water, the line is left hanging from a floating buoy, with a light, in the water for some hours, while the vessel either drifts slowly together with the line or sets other lines nearby (FAO, 2018b; Stündl, 2013). The vessel then reverses along the line at a mostly constant speed, although this can change depending on the catch and the crew. The whole operation can take up to a day but the median set time estimated from one examination of 16 vessels was 6.5 hours (de Souza et al., 2016).

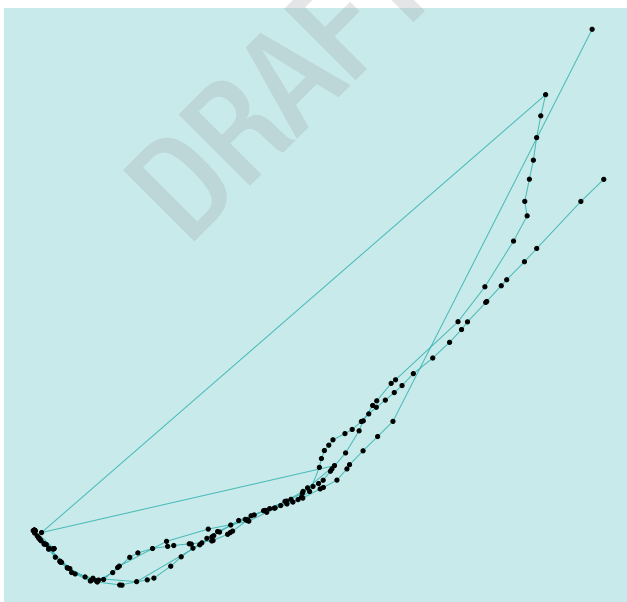
Length: Up to 100 kilometres (de Souza et al., 2016).

Mapping spatial-temporal movement patterns, as shown in Figure A2, is useful in comparing and identifying long-lining. Long-lining typically presents as complex movements as vessels lay out multiple lines and/or drift in currents, and reverse to recover lines.

A2.3.1 Chinese multipurpose vessels

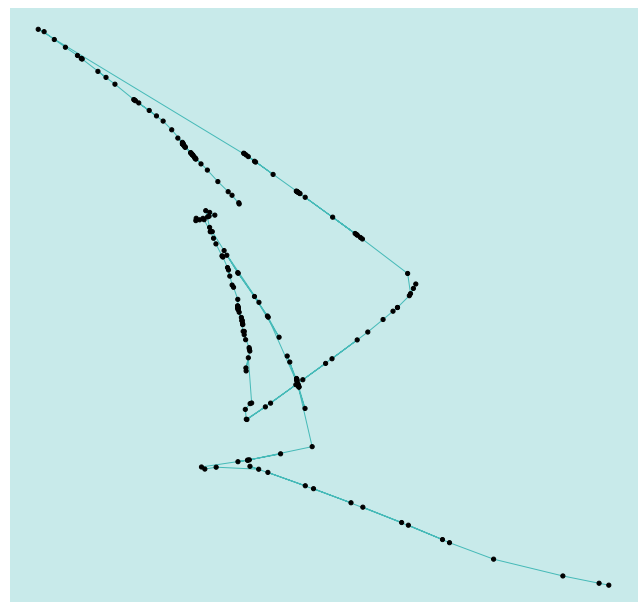
These vessels combine long-lining with trawling. The Krakken® database describes 137 Chinese vessels as multipurpose vessels.

Figure A1 Trawling by the Chinese DWF fleet



Source: elaborated from FishSpektrum (2018).

Figure A2 Long-lining by the Chinese DWF fleet



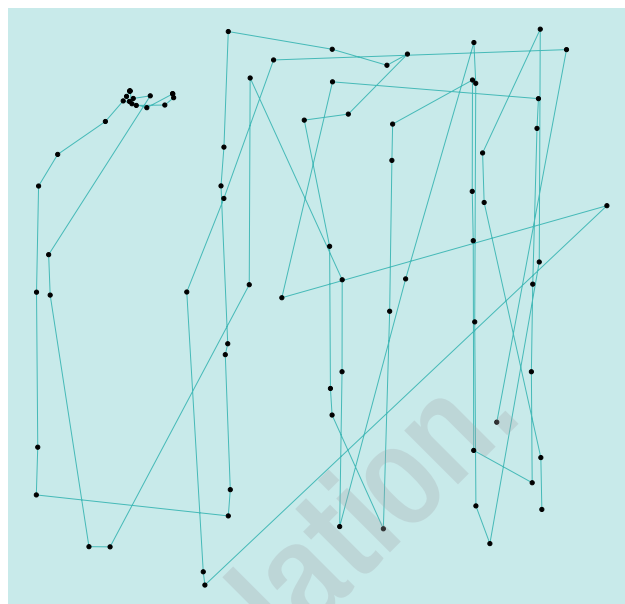
Source: elaborated from FishSpektrum (2018).

Figure A3 Squid-jigging by the Chinese DWF fleet



Source: elaborated from FishSpektrum (2018).

Figure A4 Trap-setting by the Chinese DWF fleet



Source: elaborated from FishSpektrum (2018).

The Chinese multipurpose vessel is a new type, derived from the traditional dry cargo ship. It retains the characteristics of traditional dry cargo ships, with low speed and good manoeuvrability, but has improved layout to expand cargo adaptability and loading efficiency (EWorldship, 2016).¹⁴

A2.4 Squid-jigging

Squid-jigging involves a group of fishhooks fastened together with radiating points for catching squid (Bjarnason, 1992). Jigs of various types, makes and colour are attached to a hand-line at intervals of 70 cm–90 cm. One line often holds as many as 8–12 jigs, and many more are used on automated squid-reeling systems (Bjarnason 1992). Squid-jigging often takes place at night, with bright lights to attract the squid, with groups of vessels. It requires little modification to general hand-line gear and can be a seasonal activity to supplement existing hand-line operations or any other traditional fishing (Bjarnason, 1992). The FAO characterises squid-jigging as ‘pole and line (mechanised)’.

Speed: Engine off and drifting, as shown in Figure A3.

A2.5 Trap-setting

Traps are simple, passive fishing gear that allow fish to enter and then make it hard for them to escape. Some traps include chambers or pots that can be closed once the fish enter (Slack-Smith, 2001). Figure A4 shows trap-setting, which typically involves vessels moving efficiently around a grid to set and recover traps.

¹⁴ Translated by the authors.



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