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Estimating illegal fishing across the Indian Ocean

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Important disclaimer

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The key methods underlying this report, an online survey and independent expert elicitation, rely on the goodwill, support, and above all, the knowledge of individuals and organisations who provided the information contained herein.

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Acronyms and Abbreviations

ABNJ	Areas Beyond National Jurisdiction
AIC	Akaike Information Criteria
AIS	Automatic Identification System
AN-IUU	ASEAN Network for Combatting Illegal Unreported and Unregulated Fishing
API	Application Programming Interface
ASEAN	Association of Southeast Asian Nations
BET	Bigeye Tuna
BOBP-IGO	Bay of Bengal Programme Inter-Governmental Organisation
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
DWF	Distant Water Fishing
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CMM	Conservation and Management measures
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DFAT	Department of Foreign Affairs and Trade
EEZ	Exclusive Economic Zone
EU	European Union
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organisation of the UN
FIP	Fisheries Improvement Project
FSU	Fisheries Support Unit
GAM	Generalized Additive Model
GDP	Gross Domestic Product
GFW	Global Fishing Watch

IFED	Illegal Fishing Event Dataset
IGAD	Intergovernmental Authority on Development
IGAD SSP	Intergovernmental Authority on Development Security Sector Programme
IMCS	International Monitoring Control and Surveillance Network
INTERPOL	International Criminal Police Organization
IOC	Indian Ocean Commission
IORA	Indian Ocean Rim Association
IOTC	Indian Ocean Tuna Commission
IUU	Illegal, Unreported and Unregulated
LSMPA	Large-Scale Marine Protected Area
MCS	Monitoring Control and Surveillance
MCSCC	MCS Coordination Centre
MPA	Marine Protected Area
MSC	Marine Stewardship Council
MTC	Minimum Terms and Conditions
NGO	Non-Governmental Organisations
PPP	Poisson Point Process
PRSP	Regional Fisheries Surveillance Plan
QUAD	Quadrilateral Security Alliance
RECOFI	Regional Commission for Fisheries
RFAB	Regional Fisheries Advisory Body
RFMO	Regional Fisheries Management Organisation
RPOA-IUU	Regional Plan of Action for Combatting IUU Fishing
SADC	Southern African Development Community
SAIIA	South African Institute of International Affairs
SBT	Southern Bluefin Tuna

SDG	UN Sustainable Development Goals
SIOFA	Southern Indian Ocean Fisheries Agreement
SIOTI	Sustainable Indian Ocean Tuna Initiative
SKJ	Skipjack Tuna
SWIOFC	Southwest Indian Ocean Fisheries Commission
TMT	Trygg Mat Tracking
UNFSA	United Nations Fish Stocks Agreements
WWF	World Wildlife Fund
YFT	Yellowfin Tuna

Executive summary

The project provides actionable insights regarding the state of illegal fishing across the Indian ocean, as well as methodological tools for measuring progress in the fight against illegal fishing on a regional scale. The methodology is a bottom-up approach primarily based on expert elicitation, and represents a repeatable, transparent, and cost-effective approach to estimating illegal fishing on a regional scale.

Ending overfishing and IUU fishing is target 14.4 of the United Nations Sustainable Development Goals, a sub-target of 'Life Below Water'. A 2020 FAO report estimates 30% of the Indian Ocean's assessed stocks are fished at biologically unsustainable levels. For a region that is highly dependent on fish and marine resources for food and employment, deterring and eliminating IUU fishing in the Indian Ocean is critical for long-term sustainability, food security and poverty alleviation. However, despite widespread recognition of the impacts of illegal fishing action is often delayed. This is largely due to the complex nature of IUU fishing and the difficulties in quantifying the problem.

This project, which focuses explicitly on illegal fishing (excluding unregulated and unreported fishing), has four objectives. First, we aim to estimate the volume and value of illegal fishing for 30 species of interest in the Indian Ocean. Second, we aim to map hotspots for illegal fishing across the Indian Ocean basin. Third, we aim to characterize illegal fishing activities for a subset of species (e.g., fishing violation types, gears used to violate etc.). And last, we aim to identify regional policy gaps and opportunities for reform.

Fighting IUU fishing is an explicit target for the countries adjacent to the Indian Ocean, as well as several regional organizations operating in the region (e.g., Stop Illegal Fishing, FISH-i-Africa, Indian Ocean Rim Association, E€OFISH, RPOA-IUU). The last study estimating the level of illegal (and unreported) catch in the Indian Ocean was conducted in 2009. Updating two decade-old estimates is a challenging task for a multitude of reasons. First, estimating illegal activity is difficult irrespective of the focal region. Due to its inherently illicit nature, data sources useful for estimating illegal fishing are scarce. Second, building an estimate of illegal fishing is particularly challenging across the Indian Ocean basin due to the varied nature of fleets. Efforts to measure illegal fishing have in recent years focused on the capacity for remote sensing and vessel tracking to inform improved understanding.

However, although a key source in aiding understanding of activities and behaviours, there are limitations to its use and application in the Indian Ocean.

In brief, the main findings are the following.

First, we find that the volume of illegal landings across the Indian Ocean basin amounted to over 1.3 million tonnes (around 27% of total landed volume), with an estimated value of 1.3 billion USD. This estimate is based on 30 selected species, and those species represent 43.94% of total landings taken in the Indian Ocean. In terms of the value of illegal landings, shrimps and prawns, and yellowfin tuna represent significant monetary losses for the region.

Second, key hotspots of illegal fishing were around the Horn of Africa, into the Gulf of Aden, the Bay of Bengal, and off the coast of South Africa and around the French Territories. Several regions were identified and high-likelihood areas for high-risk activities, such as in the waters to the north of Mozambique where it was thought illegal transshipment was occurring. Analysis of media data indicated hotspots around India / Sri Lanka, as well as the Persian Gulf; along with expert-identified locations such as north of Madagascar.

Third, there are distinct characteristics and patterns associated with illegal fishing in the Indian Ocean and understanding them can guide decision makers to the appropriate management tools. The profiles of perpetrators, and their specific violations, are diverse. Regionally there has been a strong focus on illegal activities of international vessels from distant water fishing (DWF) nations, and much effort has been devoted to the monitoring of tropical tuna species. However, species such as neritic tuna are also being targeted, which is of concern as they are a critical part of livelihoods for some coastal states. Additionally, incursions and activities are not solely limited to DWF nations. Vessels from countries within the region are also responsible for illegal fishing on both the high seas as well as neighbouring Exclusive Economic Zones (EEZs). Moreover, domestic vessels are reported to concentrate illegal fishing efforts in specific areas, which, combined with localized inadequate licensing and monitoring, is a concern for countries with significant small-scale fisheries. Importantly, the drivers of illegal fishing perpetrated by small, domestic vessels were widely reported to be the lack of alternative livelihoods, highlighting the importance of tackling local poverty traps. Additionally, the extent of illegal fishing was reported to be increasing, particularly so within EEZs, though the trend was less clear within the high seas. Nonetheless, several high seas issues stood out, such as the rise in unregulated squid fishing, as well as the use of large driftnets in

specific locations. The socio-economic impact of illegal fishing on coastal states included loss of jobs and lack of employment opportunities due to the closure of fishing factories, decline in specific fish stocks (such as prawn) impacting community food security and loss of local revenue due to illicit financial flows and foregone licensing revenues.

Finally, we identified key strengths and gaps of fisheries governance in the Indian Ocean. Collaboration and information sharing has increased tremendously in some parts of the Indian Ocean, notable amongst East African states. Regional surveillance plans that have enabled and supported countries to conduct joint patrols in EEZs have proved very successful. However, more intense collaboration with northern Indian Ocean states is warranted. Indeed, further regional collaboration on shared issues could enable countries to expand the monitoring, control, and surveillance of domestic inshore fisheries. Additionally, institutional fragmentation on national levels was reported. More specifically, the current lack of in-country collaboration across departments or ministries often hampers effective policymaking and enforcement. Aside from institutional fragmentation, the lack of resources and infrastructure was widely identified as a major barrier to ending illegal fishing across the region, as well as pervasive corruption. Finally, it must be noted that, aside from illegal fishing, underreported fishing was highlighted as a major violation across the region.

Expanding regional collaboration is crucial to overcoming the existing barriers to ending illegal fishing. For example, lifting decision-making and legislative action up to a regional level can help fight local corruption as well as make efficient use of exiting domestic resources. Expansion of collaboration can come in the form of increased geographic scope (i.e., further involvement of north Indian Ocean states bilaterally or in existing bodies) as well as strengthening inter-organizational ties (such as between the South African Development Community and the Intergovernmental Authority on Development) are recommended paths forward.

Project Outline

The project provides actionable insights regarding the state of illegal fishing across the Indian ocean, as well as methodological tools for measuring progress in the fight against illegal fishing (a key target of the National Plans of Action to Address IUU Fishing to the UN Sustainable Development Goals).

The project delivers four key research outputs:

- an estimation of the volume and value of illegal fishing for 30 species of interest in the Indian Ocean
- mapping of hotspots for illegal fishing across the Indian Ocean basin
- characterization of illegal fishing activities for a subset of species (e.g., fishing violation types, gears used to violate etc.)
- identification of regional policy gaps and opportunities for reform.

Additional to these research outputs is an outline as to how the approach can be used for future estimation efforts, and other relevant recommendations for addressing illegal fishing across the basin.

Ethical approval for this project was obtained from CSIRO's Social Science Human Research Ethics Committee in accordance with the National Statement on Ethical Conduct in Human Research (2007) (reference number 157/21).

1 Scope

Illegal, Unreported and Unregulated (IUU) fishing is a global problem occurring in all the world's oceans (Agnew et al., 2009; Gallic & Cox, 2006). It undermines sustainable fisheries management and threatens the food and income security of coastal communities around the world. An estimated US$15.5-36.4 billion is captured every year by illegal and unreported fishing activities, which amounts to approximately 14-33% of the global marine capture value (May, 2017). Due to the profound impacts on natural resources and the economic development of small island states particularly, IUU fishing is also increasingly recognized as a security threat (Lindley et al, 2019). As awareness of the destructive effects caused by IUU fishing grows in the international community, so does the global call for action to address the problem (Lubchenco et al., 2016). New measures have been designed and implemented to fight IUU fishing at different scales, such as the increase in domestic legislation (e.g., US Lacey Act), the implementation of novel technological tools by governments and non-state actors (e.g., blockchain tools or DNA forensics), or the increased uptake of international frameworks (e.g., Port State Measures Agreement) (Vince et al., 2021).

Ending overfishing and IUU fishing is target 14.4 of the United Nations Sustainable Development Goals (SDGs), a sub-target of SDG 14 'Life Below Water'. A 2020 FAO report estimates 30% of the Indian Ocean's assessed stocks are fished at biologically unsustainable levels. For a region that is highly dependent on fish and marine resources for food and employment, deterring and eliminating IUU fishing in the Indian Ocean is critical for long-term sustainability, food security and poverty alleviation. While 30% of the Indian Ocean falls under the jurisdiction of coastal state's EEZs the remaining 70% is classified as areas beyond national jurisdiction (ABNJ). Illegal fishing in the Indian Ocean occurs in both EEZ and ABNJ, which reflects the varied nature, impacts, and route to change that are needed for reform, at national, regional and international levels. Eliminating IUU also helps to attain other SDGs, as it would help combat illegal labour practices (SDGs 8.7 and 16.2), or enable access to nutritious food (SDGs 2.1 and 2.2) (Singh et al., 2018).

The socio-economic and political status of Indian Ocean coastal states are diverse. Developing countries make up the majority of the region's littorals, many of whom have coastal communities that rely on domestic small-scale fishery sectors for employment (Walmsley et al., 2006). However,

beyond just the small-scale fisheries, around 20% of the world's tuna comes from Indian Ocean fisheries (FAO, 2022). This includes commercially valuable tropical tuna species, including yellowfin (YFT) and skipjack (SKJ) which dominate supply for the canned tuna market.

Marine fisheries in the Indian Ocean are essential for regional food and income security, and some fisheries (such as those for tropical tunas) supply global markets. In 2020, total marine catch in the Indian Ocean (here: FAO areas 51 and 57) amounted to 12.2 million tonnes or 15.5% of global marine catch (just under its peak level in 2017 of 12.5 million tonnes) (FAO, 2022). The eastern Indian Ocean in particular (area 57) is reported to be a highly productive fisheries region with 6.6 million tonnes caught in 2020, though stock status information is very scarce and uncertain (FAO, 2022). Total landings in the western Indian Ocean reached 5.6 million tonnes in 2020. Importantly, when looking only at the tuna and tuna-like species, which are some of the most valuable fish globally, the western Indian Ocean is the more productive region of the two (67.4% of all tuna and tuna-like species catch in the Indian Ocean was sourced from the West Indian Ocean in 2020). Within the western Indian Ocean, 65.3% of stocks are fished within biologically sustainable limits, and in the eastern Indian Ocean, this drops slightly to 62.5% (FAO, 2022). There are several stocks of concern in both areas, such as the hilsa shad *(Tenualosa ilisha)* in the East Indian Ocean, and Penaeidae shrimp stocks in the west (FAO, 2022).

Fighting IUU fishing is an explicit target for the countries adjacent to the Indian Ocean, as well as several regional organizations operating in the region (e.g., Stop Illegal Fishing, FISH-i-Africa, IORA, E€OFISH). Recent reports indicate that IUU fishing remains a substantial challenge for the region (WWF and Trygg Mat Tracking, 2020), including for example, unauthorized fishing by European vessels (OceanMind, 2022), evidence of suspicious fishing patterns across the North-West Indian Ocean (TMT and GFW, 2020), and illegal fishing across the western Indian Ocean (Stop Illegal Fishing, 2017). The West Indian Ocean is one of the worst scoring ocean basins in the IUU Fishing Index (second worst out of seven basins, the East Indian Ocean places fifth), which is an independent assessment of IUU fishing covering 152 coastal countries and provides a score per country based on 40 indicators (Macfadyen et al., 2019).

The last study estimating the level of illegal (and unreported) catch in the Indian Ocean was conducted in 2009 (Agnew et al., 2009). In the West Indian Ocean, where 52% of total regional catch was included in the making of the estimate, on average 18% of catch was estimated to be caught

illegally in 2000-2003 (Agnew et al., 2009). In the East Indian Ocean, where 44% of total regional catch was included for the estimate, the estimate rose to an average of 32% (Agnew et al., 2009). As previously mentioned, updating these estimates is a challenging task.

First, estimating illegal activity is difficult irrespective of the focal region. Due to its inherently illicit nature, data sources useful for estimating illegal fishing are scarce, and to produce more reliable results researchers should triangulate multiple data sources (Macfadyen et al., 2016). Second, building an estimate of illegal fishing is particularly challenging across the Indian Ocean basin due to the varied nature of fleets. Efforts to measure illegal fishing have in recent years focused on the capacity for remote sensing and vessel tracking to inform improved understanding. However, although a key source in aiding understanding of activities and behaviours, there are limitations to its use and application. Specifically, one that has gained much attention for assessing vessel activity is Automatic Identification System (AIS). Although frequently used as a monitoring system, it is important to note that AIS is primarily a safety system, designed as an anti-collision system. Re-purposing this safety system for surveillance of fishing vessels may undermine its effectiveness for increasing safety at sea. In addition, it is important to consider the types of fisheries across the Indian Ocean, where artisanal and semi-industrial gears represent a substantial proportion of all fishing activity in the region, and as such will often not use (and are not required to use) AIS (WWF and TMT, 2020; Taconet et al., 2019). Additionally, in the western Indian Ocean, less than 50% of vessels over 24 meters use AIS (Bahrain, Seychelles and distant water longliner fleets being the exception) (WWF and TMT, 2020; Taconet et al., 2019).

It is reported that even on the high seas of the eastern Indian Ocean, AIS data does not represent fishing activity well (WWF and TMT, 2020; Taconet et al., 2019). Nonetheless, studies investigating the extent of IUU fishing have also increased over the past decade, using a variety of approaches and data sources (Vince et al., 2021). Five data sources are commonly used to estimate IUU fishing, each with its own set of strengths and weaknesses: Monitoring, Control and Surveillance (MCS) inspection data; remote sensing data (such as on-board camera monitoring or satellites); trade and catch data; stock assessments; and expert opinion (MRAG, 2005; Macfadyen et al., 2016; Donlan et al., 2020). Depending on regional data availability, studies often combine different information sources. They can be undertaken at a variety of scales, from subnational to regional, but most studies take the EEZ as their focal point (Macfadyen et al., 2016). However, despite an increase in studies, robust, transparent, large-scale estimates of the extent of IUU fishing remain scarce

(Macfadyen et al., 2016). Moreover, some existing studies have been deemed insufficiently transparent about information sources, assumptions, and methodological weaknesses, and often produce estimates that are not robust (Macfadyen et al., 2016). Additionally, existing estimates are challenging to combine to get a global estimate, as methodologies have been inconsistent (Macfadyen et al., 2016). Consequently, the last global estimate of illegal fishing dates from 2009 (Agnew et al., 2009) uses the 'anchor points and influence factor' method (Pitcher et al. 2002), a method which has been critiqued for its high uncertainty and lack of transparency (Macfadyen et al., 2016; Hilborn et al., 2019).

To strengthen the quality and consistency of future studies and to ensure they produce estimates that can be combined to a global estimate, the FAO is developing a set of technical guidelines (FAO, 2021). In general, the draft guidelines divide IUU estimation methodologies into top-down and bottom-up methods and, though they do not provide a single superior methodology, offer a set of guiding principles to improve the quality of IUU fishing estimations for both types. Top-down approaches estimate an overall quantity of missing catch and bottom-up approaches are typically used to measure the extent of one or multiple IUU fishing activities at a more granular scale (FAO, 2021). The guidelines require that studies deliberately consider, and transparently communicate, aspects such as the objectives, scope, risks, methodological design, considerations of gaps, biases, and uncertainty. Here we propose a multi-method approach to estimating illegal fishing (excluding unreported and unregulated fishing) based on those technical guidelines.

The aim of this study is to provide information on illegal fishing across the Indian Ocean basin, an area which consists of three FAO major fishing areas: the West Indian Ocean (area 51), the East Indian Ocean (area 57) and the Antarctic and South Indian Ocean (area 58). *(Please note that the FAO also describes the Indian Ocean to include only areas 51 and 57. See Figure 1, the total area of interest is depicted, stretching from 30°00'E to 150°00'E, from Antarctica in the south up to the Arabian Sea and Bay of Bengal.)* In the West Indian Ocean, approximately 42% of marine waters fall under national jurisdiction, and 58% is high seas. In the East Indian Ocean, approximately 29% of the total area falls under national jurisdiction and approximately 71% is high seas (Taconet et al., 2019).

Our methodology is a bottom-up approach primarily based on expert elicitation, and represents a repeatable, transparent, and cost-effective approach to estimating illegal fishing on a national or

regional scale. The approach has already been used to estimate levels of illegal fishing in the Asia-Pacific Fishery Commission (APFIC) region (Wilcox et al., 2021), as well as on a national scale in Chile (Donlan et al., 2020). More specifically, the methodology provides:

- an estimate of the volume and value of illegal fishing;
- an overview of illegal fishing hotspots;
- an in-depth characterization of illegal fishing practices;
- identification of regional policy gaps and opportunities for reform.

The results can potentially help to inform policies and practices designed to combat illegal fishing in the chosen region, and the methodology can be used to track illegal fishing in the future. For example, a survey can be sent out periodically to officers to acquire an estimate of the volume and value of illegal fishing and information on illegal fishing hotspots, either in the entire region or specific EEZs. In this way, states and regional bodies can track progress on illegal fishing in a low-cost manner.

2 Methodology

2.1 Species selection

One of the goals of this project is to provide an estimate of the volume and value of illegal fishing in the region. Following here is an outline of the species included in the project. Please note that only the species included in the survey for fisheries officers were used for the estimation of the volume and value of illegal fishing.

For the area of interest (Figure 1), in the first instance, 30 species of interest were selected. These species were selected based on being targeted by either industrial or small-scale fishers, with activities taking place either in countries' EEZs or the high seas. Those 30 species were selected for the project based on three metrics:

1. Volume of the species caught in the entire region. Higher catch volume species were put higher on the priority list (catch volumes obtained via FAO global marine capture database);
2. Value of the species caught in the region. Higher value species were put higher on the priority list (Sea Around Us ex-vessel price dataset (average of 2010 USD prices for years 2014-2016);
3. Level of priority according to regional experts (such as officers active in national fisheries ministries or RFMOs).

The number of species was capped at thirty as the primary method for data collection is surveys, and including a large set of species can make it difficult for survey participants to keep oversight of the questions and coherence of answers. Moreover, survey length is a known concern for survey reliability, as long surveys are taxing on the attention spans of participants (Gideon, 2012). However, at the request of one of the participating countries, an additional species was inserted for the country's fisheries officers, i.e., coral reef fish. With this addition, the list of pre-selected species comes to 31 species (Table 17).

A second set of 30 species was selected to ensure our project also covered the primary species targeted on the high seas of the Indian Ocean (Table 17). The 30 species in this second selection are managed by one of the four regional organisations (IOTC, SIOFA, CCAMLR and CCSBT). Of those 30, 15 species are managed by IOTC, one of those by CCSBT, i.e. the Southern Bluefin Tuna, 4 are under the management of CCAMLR, and 10 are managed by SIOFA. The species managed by IOTC, CCAMLR

and CCSBT are those listed on their respective websites, and the remaining 10 SIOFA-managed species were selected from a SIOFA species priority list.

The final list of species included in the project comes to 50 unique species (and specie groups), as 11 species overlapped between the initial and second set of species. The first set of species was evaluated in a survey by fisheries officers, knowledgeable on illegal landings within EEZs, and the second set by fisheries observers, knowledgeable on illegal catches on the high seas. Aside from these 50 unique pre-selected species which were included in the surveys, respondents were also able to suggest species of importance and add them to the survey as they were filling the survey out.

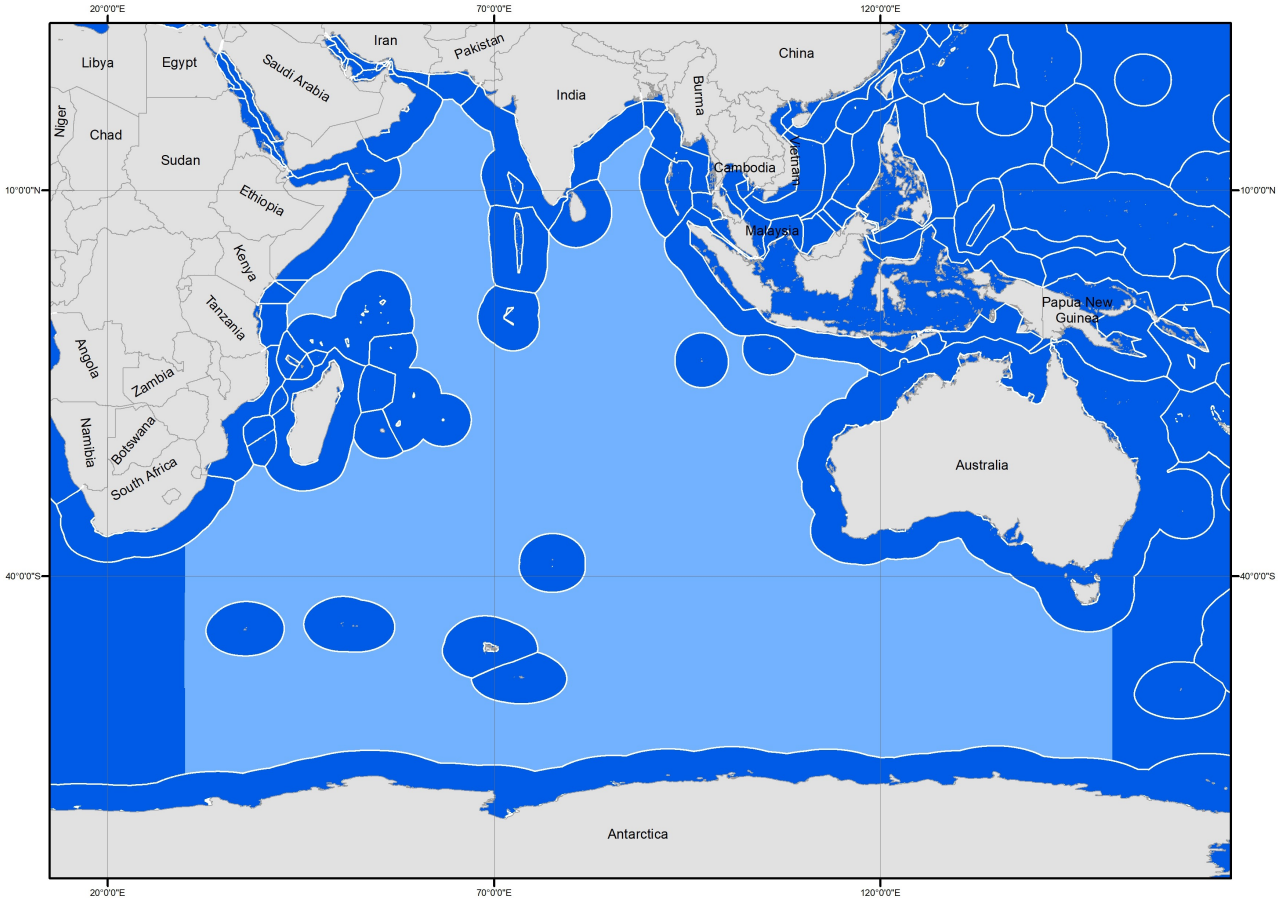

Figure 1: Indian Ocean. High seas areas of the Indian Ocean are shaded in light blue, and country EEZs in dark blue.

The list of selected species represent a mix of those targeted by small-scale fishing vessels (artisanal/ subsistence sector) and industrial vessels (i.e., larger than 12 meters in length, commercial sector), and includes both neritic and high seas species. Only species that are covered by a management regime (which can be national management regimes or regional, such as by an RFMO) were included, to ensure the estimates capture illegal fishing rather than unregulated fishing. Species caught primarily as by-catch were not a focus, as those would not be primary targets of illegal fishing, unless experts expressed these species to be of great priority (such as certain sharks).

Table 1 Species included in the study. There are 11 species/specie groups that overlap between the coastal and high seas species, indicated in bold. Note: only the species included in the survey for fisheries officers were used for the estimation of volume and value of illegal fishing.

Species included in survey for fisheries officers (coastal focused)				
Abalones	Groupers	Indo-Pacific King Mackerel	Lobsters	Octopus
Rainbow runner	Coral groupers	Croakers & drums	Lizardfishes	Sea cucumbers
Longtail tuna	Short mackerel	Clupeoidei	Indian oil sardine	Sharks
Indian mackerel	Yellowfin tuna	Ponyfishes	Talang queenfish	Skipjack tuna
Marine turtles	Shrimps & prawns	Frigate & bullet tunas	Striped marlin	Decapterus species
Kawakawa	Swordfish	Squids	Bombay duck	Southern bluefin tuna
Coral reef fish (upon country request)				
Species included in survey for fisheries observers (high-seas focused)				
Yellowfin tuna	Narrow-barred Spanish mackerel	Mackerel icefish	Skipjack tuna	Indo-Pacific king mackerel
Antarctic krill	Bigeye tuna	Blue marlin	Splendid alfonsino	Albacore tuna
Black marlin	Oilfish	Southern bluefin tuna	Striped marlin	Orange roughy
Longtail tuna	Indo-Pacific sailfish	Decapterus species	Kawakawa	Swordfish
Saurida species	Frigate tuna	Patagonian Toothfish	Kitefin shark	Bullet tuna
Antarctic tooth-fish	Portuguese dog-fish	Bluenose warehou	Black cardinal fish	Spiky oreo

2.2 Illegal fishing definition

This project is primarily focused on gathering information on, and measuring, illegal fishing. This, in theory, excludes unreported and unregulated fishing, though it can certainly be argued that not reporting or under-reporting catches is a type of illegal fishing. To collect information on illegal fishing activities across the Indian Ocean, the following guides and outlines were used to delineated what activities would entail in our project.

The FAO (2001) defines illegal fishing as follows:

- conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations;
- conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organization but that operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international law; or
- in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization.

Based on the above definition, we consider a fishing vessel engaged in an illegal fishing activity if it carries out one of the following activities in contravention with the conservation and management measures applicable in an area:

- Fishing without, or in violation of, a valid license
- Fishing or transhipping protected species or undersized species
- Fishing for species for which no quota was allocated or for which the quota has been caught
- Fishing in a closed area
- Fishing during a closed season
- Using unauthorized gear to fish
- Fishing or transhipping without a nationality or with a false/concealed identity or registration (e.g., false vessel name and/or IMO number)
- Undertaking unauthorized transshipment (i.e., transfers of fish to other vessels such as reefers)
- Fishing in an RFMO area without being on the authorised vessel list
- Fishing in the coastal waters of a State without permission

- Other on-water activities in breach of applicable laws and regulations (including those adopted by RFMOs and international levels).

2.3 Data collection

To provide information on illegal fishing across the Indian Ocean basin, we use a combination of three data sources: a structured survey, semi-structured interviews and media data. Here we describe the data collection process for all three data sources, and how that data was subsequently analysed to fulfill our research objectives:

- estimating the volume and value of illegal fishing for 30 species of interest in the Indian Ocean
- mapping hotspots for illegal fishing across the Indian Ocean basin
- characterizing illegal fishing activities for a subset of species (e.g., fishing violation types, gears used to violate etc.)
- identifying regional policy gaps and opportunities for reform

Table 2 Outlines the links between objectives, data sources, and the methods of analyses which follow.

Objective	Data source	Description of data	Data analysis tool(s)
Estimation of value & volume	Survey for fisheries officers	Estimation of value / volume of illegal fishing at species, subregional and regional level (30 species)	Bayesian cumulative multinomial logit model
	Media data	Independent estimation of value/volume of illegal fishing from reported illegal fishing incidents	Regression trees
Overview of illegal fishing hotspots	Surveys (fisheries officers & observers)	Locations obtained through clickable map	Poisson Point Process model
	Media data	Independent source of data for locations from reported illegal fishing incidents	Deep learning classifier and entity recognition tools
	Interviews	Narrative answers illustrating certain characteristics of illegal fishing practices such as infraction type	Text analysis

An in-depth characterization of illegal fishing	Surveys (fisheries officers & observers)	Data sourced from questions on a subset of priority species. Data collected on characteristics such as infraction type and supply chain dynamics.	Extraction and description of characteristics
	Media data	Data collected on available characteristics such as vessel flags and infraction types.	Deep learning classifier and entity recognition tools
	Interviews	Narrative answers illustrating certain characteristics of illegal fishing practices such as infraction type	Text analysis
An assessment of the efficacy of governance practices and policies	Interviews	Narrative answers regarding governance of illegal fishing in the region (e.g., drivers of illegal fishing, successful policies)	Text analysis

2.3.1 Surveys

Target audiences and outreach procedure

The primary source of information on the extent and nature of illegal fishing is fisheries officers in coastal countries and fisheries observers active on the high seas of the Indian Ocean. Fisheries *officers* are targeted because of their direct experience with the occurrence of illegal fishing activities. Typically, officers work in ports or out at sea. In port, they inspect fishing boats to ensure all laws prevailing in a coastal state were followed. Fisheries officers can also do sea patrols and, when boarding a vessel, they inspect catches and ensure that catch reports are correct. Fisheries *observers* are deployed on commercial fishing vessels to monitor and record fishing information and/or to collect biological data. They are often contracted by countries or through RFMOs to inspect vessels operating on the high seas.

A unique survey was circulated to each of the two participant groups: one survey containing questions regarding the mix of neritic species and high seas species, targeted at fisheries officers, and a survey containing only high seas species, targeted at fisheries observers. Both surveys were made available in a suite of languages to ensure participants were fully understanding of the survey

content. Fisheries officers and observers were asked to fill out the survey via an online form which was disseminated through relevant regional organizations and national officials. All participants remained anonymous.

The survey designed for fisheries officers targeted all officers active in the EEZs of countries that fish in either the East or West Indian Ocean (deducted from the FAO global marine capture database), and that are directly adjacent to one of those subareas. Consequently, fisheries officers from for example China or Japan were not contacted to partake in the survey for fisheries officers because, even though China and Japan both have active fisheries in the Indian Ocean, they are not directly adjacent to any of the Indian Ocean subareas. National point of contact was often identified through several regional meetings organized by, for example, the South-West Indian Ocean Fisheries Commission (SWIOFC), the Southern African Development Community (SADC) or the ASEAN network for combatting IUU fishing (AN-IUU). Fisheries officers were also engaged via regional organizations focused (in part) on the eradication of IUU fishing such as E€OFISH, or Stop Illegal Fishing. A variation of the survey for fisheries officers was provided upon request by the coastal countries. We acquired 79 survey responses total (though surveys are not all completed, as for example questions not applicable to the officer's experience could be skipped or people exited the survey at various stages). The survey designed for fisheries observers was distributed through regional organisation, via contacts obtained through RFMOs including, i.e., the Indian Ocean Tuna Commission (IOTC), Southern Indian Ocean Fisheries Agreement (SIOFA), Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and Commission for the Conservation of Southern Bluefin Tuna (CCSBT) (Table 1). Those contacts were either private entities responsible for the hiring and/or training of regional observers for an RFMO, or national observer coordinators. We acquired 23 total survey responses, with 16 of those completed.

Contents of the surveys

Both surveys were designed to gather information regarding two out of four objectives described above, namely to obtain an overview of illegal fishing hotspots, and an in-depth characterization of illegal fishing practices. The survey for fisheries officers is also used for an additional objective, namely to estimate the volume and value of illegal fishing in the Indian Ocean. The survey for fisheries observers is not used for that estimation as observers do not work directly with landings of species.

For the first objective, i.e. acquiring an estimate of the volume and value of illegal fishing in the region, officers were asked to estimate levels of illegal landings for 30 species and specie groups (Table 1), with one specialized country-specific survey containing 31 species (with the addition of coral reef fish upon request). Respondents could select one of six response options: none of the landings in the past 12 months of this species involved illegal fishing activities, or little, less than half, more than half, almost all or all. Respondents also indicated the certainty of their answer per species.

Second, to acquire information on illegal fishing hotspots, officers and observers were asked to spatially locate up to 20 areas on a map they judged to be hotspots across the entire Indian Ocean.

Third, to acquire information regarding the specific characteristics of illegal fishing, officers and observers were asked a unique set of questions in their respective surveys. The officers were asked to first select their subregion of expertise (see Figure 2 for the available subregions) and subsequently answer eight questions regarding a maximum of five species. The species are a subset of the thirty species outlined in Table 1. Three focal species were pre-selected (again based on catch volume, value and expert input), one species was selected by the participant and a potential fifth species filled in by the participant (which was optional). Table 3 shows the pre-selected focal species per subregion. Please note: there are four additional species for area 2 as one country-specific survey was sent out for this area, with additional focal species (upon request of the country). The in-depth questions for all focal species inquired about the following six characteristics of illegal fishing:

- The involvement of small versus large-scale vessels in illegal fishing activities per species
- The types of infractions taking place, disaggregated between small-and large vessels
- The type of regulations being breached (National, bilateral or international)
- The actors involved in illegal fishing activity along the supply chain per species
- The destination markets for illegally caught fish (local, national or international) per species
- The gear types involved in the illegal activities per species

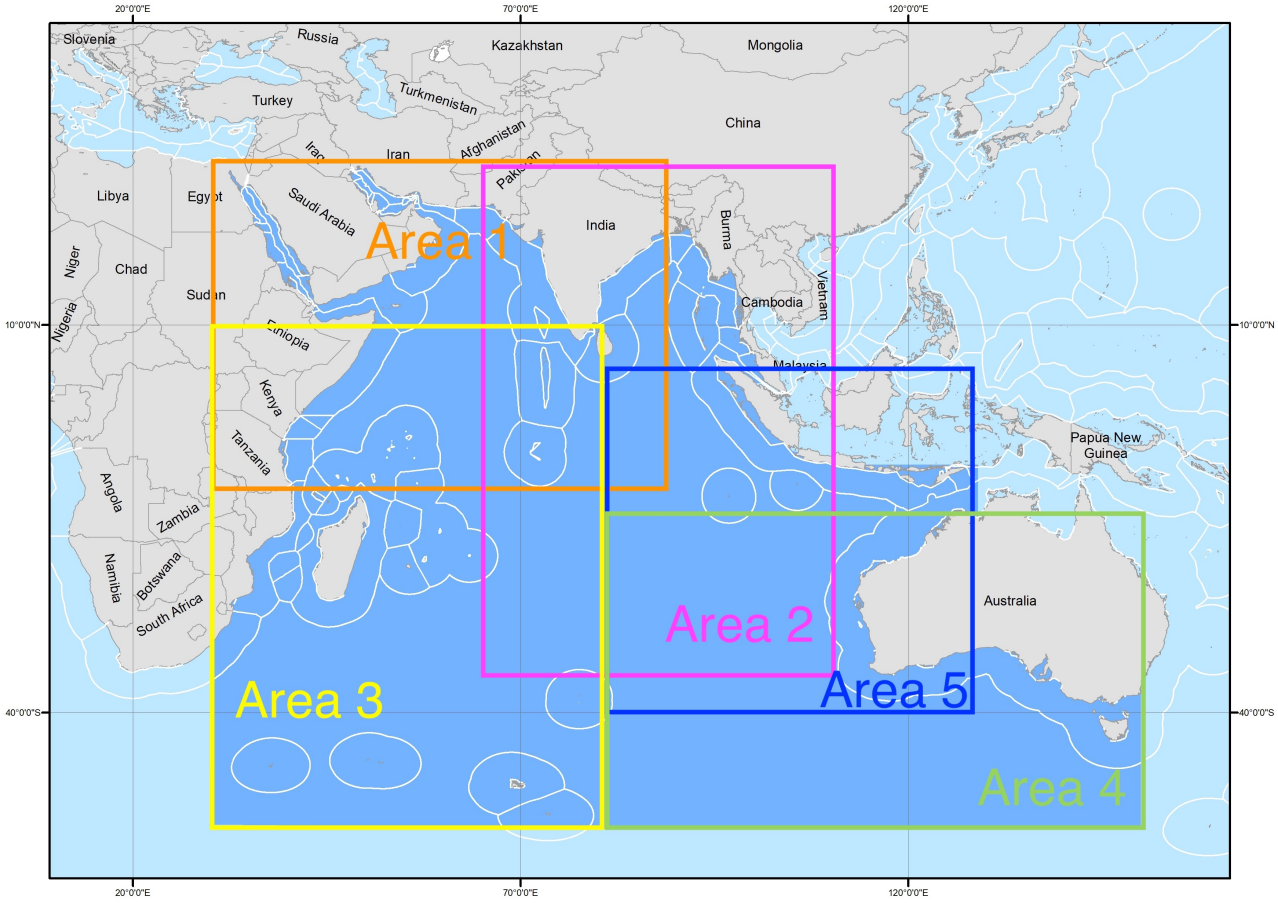

Figure 2 Subregions of expertise available for selection by the respondent. Selection of the subregion determined which focal species the respondent would be asked questions about.

Table 3 Focal species for each subregion. Species with an asterix (*) are those that were additionally pre-selected for one country specific survey)

Area	Focal Species
Area 1	Sharks Squids Indian oil sardine
Area 2	Lobsters Yellowfin tuna Southern bluefin tuna Kawakawa* Coral groupers* Sharks* Coral reef fish*
Area 3	Sharks Indian oil sardine Striped marlin
Area 4	Striped marlin Southern bluefin tuna Lobsters
Area 5	Sea cucumbers Sharks Yellowfin tuna

Fisheries observers were asked two in-depth questions regarding a respondent-determined subset of species:

- Level of experience of the respondent with each species in terms of illegal fishing
- Ranking of the species from most to least impacted by illegal fishing

Then they were asked six additional in-depth questions which were not species-specific:

- The types of infractions taking place, dis-aggregated between small-and large vessels
- The gear types involved in the illegal activities per species
- Ranking of occurrence of unreported and unregulated fishing and illegal fishing
- Involvement of bunkers and reefer vessels
- Fill in a species linked to unregulated fishing
- Fill in a species linked to unreported fishing

2.3.2 Media data

Second, we used publicly available media as an additional independent source of information for the first three objectives, namely to obtain:

- an estimate of the volume and value of illegal fishing in the Indian Ocean
- an overview of illegal fishing hotspots
- an in-depth characterization of illegal fishing practices incidents

All of those are independent of the surveys and to be compared with those outcomes. An application programming interface (API) was used to access media data from LexisNexis and pulled 149 937 unique articles via seven queries. The queries were run starting from December 2021 through to February 2022. From the entire set of unique articles, 148 864 had entries for LexisNexis 'content' tag. 147 835 of those remaining articles were written in the English language (much of the remainder of the articles were written in Indonesian). Those 147 835 articles represent the final set of media data to extract illegal fishing events from. The earliest articles were published on the first of January 2011, and the last on the 20th of December 2021 (i.e., representing just over a decade of data).

In total, 2874 articles were annotated by two annotators, where the positive class (i.e., class with label 1) signifies that at least one illegal fishing event is present in the article, and 0 denotes the absence of an illegal fishing event. For an article containing an illegal fishing event to be included in the dataset, it needed to:

- Refer to an illegal fishing act either explicitly (e.g., vessel was caught fishing illegally) or through the mention of acts expressed to be illegal (e.g., the person used unauthorized gear; the vessel caught undersized species against conservation laws;...);
- Refer to an act undertaken by one/multiple fisher(s) or vessel(s), or fleet (as opposed to the illegal trade of fish by intermediaries, for example);

- Refer to an act undertaken in marine waters;
- Refer to an act that was completed (can be both recent or in a more distant past), or steps have been made to undertake it in the near future (e.g., setting up lobster traps in a protected area for future illegal catch).

From the 2874 annotated articles, 406 are labelled as an illegal fishing event (1), and 2468 as not an illegal fishing event (0). A Transformer-based model was used, more specifically the Long-Document Transformer or 'Longformer' (Beltagy et al., 2020), to filter out illegal fishing events. The model was trained in the Google Colab Pro environment on 2299 annotated articles (i.e., 80 percent of all annotated articles) and subsequently validated on 287 articles (approximately 10 percent of all articles). The hyperparameters of the Longformer model (i.e., batch size, epochs, learning rate, warm-up steps and weight decay) were optimized in order to construct the best performing model. This model had recall of 0.8 for the positive class on the validation set. That model was used on the test set (n = 288, also approximately 10 percent of all annotated articles) to evaluate performance, and it had a recall of 0.75 for the positive class on this unseen, annotated test set. The final model was used on the unannotated data (n = 144 959), and it marked 21684 articles (14.9%) as containing illegal fishing events. Together with the 406 illegal fishing events labelled by the two annotators, the total dataset came to 22 090 media articles.

We then identified and extracted the specific sentences within each article contained in the dataset that contain the illegal fishing event. To do so, we use a SetFit model, a text classification model that can achieve high accuracy with limited labelled data and is based on the sentence-transformers library (Ruder, 2021). Before applying the SetFit model, we pre-process the 22 090 articles within the dataset to individual sentences. We then fine-tune a pretrained SetFit model ('paraphrase-mpnet-base-v2') to filter out the sentences containing the illegal fishing event. This model had recall of 0.6 for the positive class on the validation set.

The resulting dataset contains all sentences that were marked by the SetFit model to contain an illegal fishing event (as well as those sentences marked by the annotator to train the model in the first place), which were 65 013 sentences. From all the sentences marked as containing illegal fishing events, we only kept those that mentioned a fish species (or the general word 'fish') or a gear type (such as 'trawler' or 'gillnet'), and removed any sentences that referred to freshwater entities (such as 'lake') to ensure only relevant sentences were retained. As a result, we have a dataset containing sentences belonging to 12 139 unique media articles.

Finally, we extract the relevant information from those sentences, namely:

- Species mentioned in event (gazetteer containing both species reported against in the FAO capture database and the Atlas of Living Australia (ALA))
- Violation type reported in event if any (gazetteer containing violation types put together by author team)
- Penalty type reported in event if any (gazetteer containing penalty types put together by author team)
- Industry type reported in event if any (gazetteer containing industry types put together by author team)
- IORA country mentioned in event if any (gazetteer containing IORA countries put together by author team)
- Quantity of vessels/fishers involved (SpaCy tool)
- Quantity of illegal catch taken (SpaCy tool)
- Location of event (outlined below)
- Date the media article was reported (from LexisNexis)
- Country where media article was published (from LexisNexis)
- Media source (from LexisNexis)

For that purpose, we use both in-domain gazetteers (for gear type, violation type, penalty type, industry type, species and IORA country mentioned) and off-the-shelf Named Entity Recognition (NER) Annotation tools from SpaCy (for quantities and locations). LexisNexis provided data on the date, country and source of publication. To determine the location of the event, we used the following process:

- Where possible, we created our own 'geolocation tag'. The first step involves collecting the latitude, longitude, and formatted address for locations identified in the sentence via an off-the-shelf SpaCy tool ('NER'). To do so, we used the GoogleMap geocoding API (https://developers.google.com/maps/documentation/geocoding). To help us identify the correct location (sometimes the same location name exists in multiple countries), we use location-related entities such as geopolitical entities mentioned in the sentence, as well as data on the country of the publisher provided by LexisNexis. In cases where multiple locations are still detected, a decision process is used to determine the main location of the event. If only one location is detected, it becomes the main location. If two locations are found, the finer-

grained location (e.g., city level versus state level) is chosen. In the case of three or more locations, a centre point is calculated from their latitude and longitude, and the closest location to that centre point is chosen as the main location. If no locations are detected from the initial sources, the logic falls back to using locations from the context of the event (i.e., the surrounding sentences) and the news company's title. A centre point is again calculated and the closest location to that point is selected as the main location.

- If we could not create a geolocation tag due to missing data, we used the country of the publisher, provided by LexisNexis, as the location of the illegal fishing event.

Because different media articles can cover the same illegal fishing event, we removed any 'duplicate events'.

An event is a duplicate of another event if it has all the following characteristics:

- The same species or word 'fish' in the sentence
- The published date occurs within the same month
- The event is tagged to the same location (at a country-level)

The final dataset (from hereon called the Illegal Fishing Event Dataset (IFED)) contains 8828 unique illegal fishing events, i.e., sentences that report on a unique illegal fishing event. For all events, we have a publication date, a location (which can be either a location mentioned in the sentence or the country where the article was published), media source and a species. For some proportion of articles, we have a reported violation, penalty, industry, quantity of vessels/fishers involved and quantity of illegal catch taken. The event dates range from 2011 to 2021 (covering a decade of data).

From the IFED, we extracted a subset of data relevant to IORA (i.e., either published in an IORA country or the event mentions an IORA country) within the timeframe of 2019-2021. This resulted in a subset of 731 illegal fishing events.

2.3.3 Economic Analysis

Analysis of the IFED provides a snapshot as to the species, quantities and value of illegal fishing in particular events, as well as who was undertaking the activities. As these are based on what was on the vessels at their time of interception, they provide only a lower bound to the level of illegal fishing and are independently verified. How many illegal trips were undertaken by these vessels before

interception, and how characteristic the catch was that was intercepted of these vessels is not known, nor how many other vessels that were not intercepted were active at the time. Differences in the number of events between countries may also reflect differences in surveillance and enforcement activity rather than relative levels of illegal fishing. Nevertheless, these reports reflect the types of activities that are occurring, and who is involved (domestic fishers or foreign flagged vessels; large boats or small artisanal boats etc).

Events identified in the media

Information on the type, and where available, quantity of catch was also collected from media reports over the period 2019-2021 using LexisNexis, from which 731 individual reports were identified as relevant to the Indian Ocean region. These reports were individually assessed for content. Reports that mentioned illegal fishing without details were removed. These included media stories that blamed IUU for decline in fish stocks or mortality of marine mammals and turtles, or mentioned fishers reporting sighting illegal fishing activities in their area. Other media articles reported the introduction of new policies or surveillance activities to reduce IUU. A number of articles (n=49) also reported activities outside the region of interest. Only reports of specific IUU activities with at least identification of the species impacted and some indication of the number of people or boats involved were retained (n=276, 38% of the total number of reports initially identified).

Most of these reports (n=174) included information on species caught, who caught it (foreign or domestic boats or people), quantity of catch (either as a weight or value) and some indication of how many individuals and/or boats were involved. A number of these reports (n=53) provided estimates of the value of catch directly, with around half of these (n=26) providing both quantity and value allowing an estimate of prices to be derived. Where quantity (but not value) information was available, the value of the catch was estimated using price information, derived from several sources (Table 1). All prices were converted USD and to 2021 real values based on the US CPI.

Table 4a: Prices used to derive value of catch (indexed to 2021, USD).

Species	Price ($/kg)	Source
Abalone	$139.34	Derived from the reported values
Blue Swimmer Crab	$6.98	Derived from (Therneau & Atkinson, 2019)
Bluenose	$7.82	Derived from the reported values
Cockle	$8.82	Derived from (Tuynman & Dylewski, 2022)
Conch Shell	$126.03	Indian import data (per piece) (a)
Coral (fans)	$19.13	Seafan market price (per piece) (b)
Crab	$6.98	Derived from (Tuynman & Dylewski, 2022)
Dugong	$3.38	Assumed same as whale shark
Fish	$5.19	Derived from (Wilcox et al., 2021)
Kingfish	$3.28	Generic fish price
Lobster	$41.09	Derived from (Wilcox et al., 2021)
Mud Crab	$6.98	Derived from (Tuynman & Dylewski, 2022)
Periwinkle	$8.82	Estimated wholesale price (c)
Redclaw	$19.47	Derived from (Tuynman & Dylewski, 2022)
Sea Cucumber (dried)	$286.31	Derived from the reported values
Sea Snail	$39.63	Derived from (Wilcox et al., 2021)
Seahorse (dried)	$1,512.4	Derived from the reported values
Shark	$6.89	Derived from (Wilcox et al., 2021)
Shark Fins	$17.20	Derived from (Wilcox et al., 2021)
Shrimp	$9.53	Derived from the reported values (d)
Snapper	$3.28	Generic fish price
Sponge	$56.67	Derived from the reported values
Squid	$3.90	Derived from (Wilcox et al., 2021)
Tuna	$2.57	Derived from (Wilcox et al., 2021)
Turtle	$5.83	Derived from (Wilcox et al., 2021)
Whale Shark	$3.38	Reported price (e)
Yellowfin Bream	$3.28	Generic fish price
Yellowfin Tuna	$2.52	Derived from (Wilcox et al., 2021)

(a) https://www.zauba.com/import-conch+shells-hs-code.html;

(b) https://www.worldwidewildlifeproducts.com/store/pc/DriedSea-Fan-Coral-c217.htm;

(c) https://www.wholesaleshells.co.uk/emperor-purple-periwinkle-p-7801.html;

(d) https://www.indiatoday.in/magazine/environment/story/20010611govt-bans-slaughter-trade-of-whale-sharks-775083-2001-06-10;

(e) also consistent with estimate derived from Wilcox et al. (2021).

The remainder (n=102) reported species caught and usually some indication of the number of individuals and/or boats involved, but without an estimate of catch quantity or value. Estimates of the value associated with these reports were made using a regression tree derived from the subset of data with value data available, following an earlier approach reported in (Wilcox et al., 2021). Fish (unspecified in most cases) was the predominant target of IUU fishing identified in the data (Figure 3).

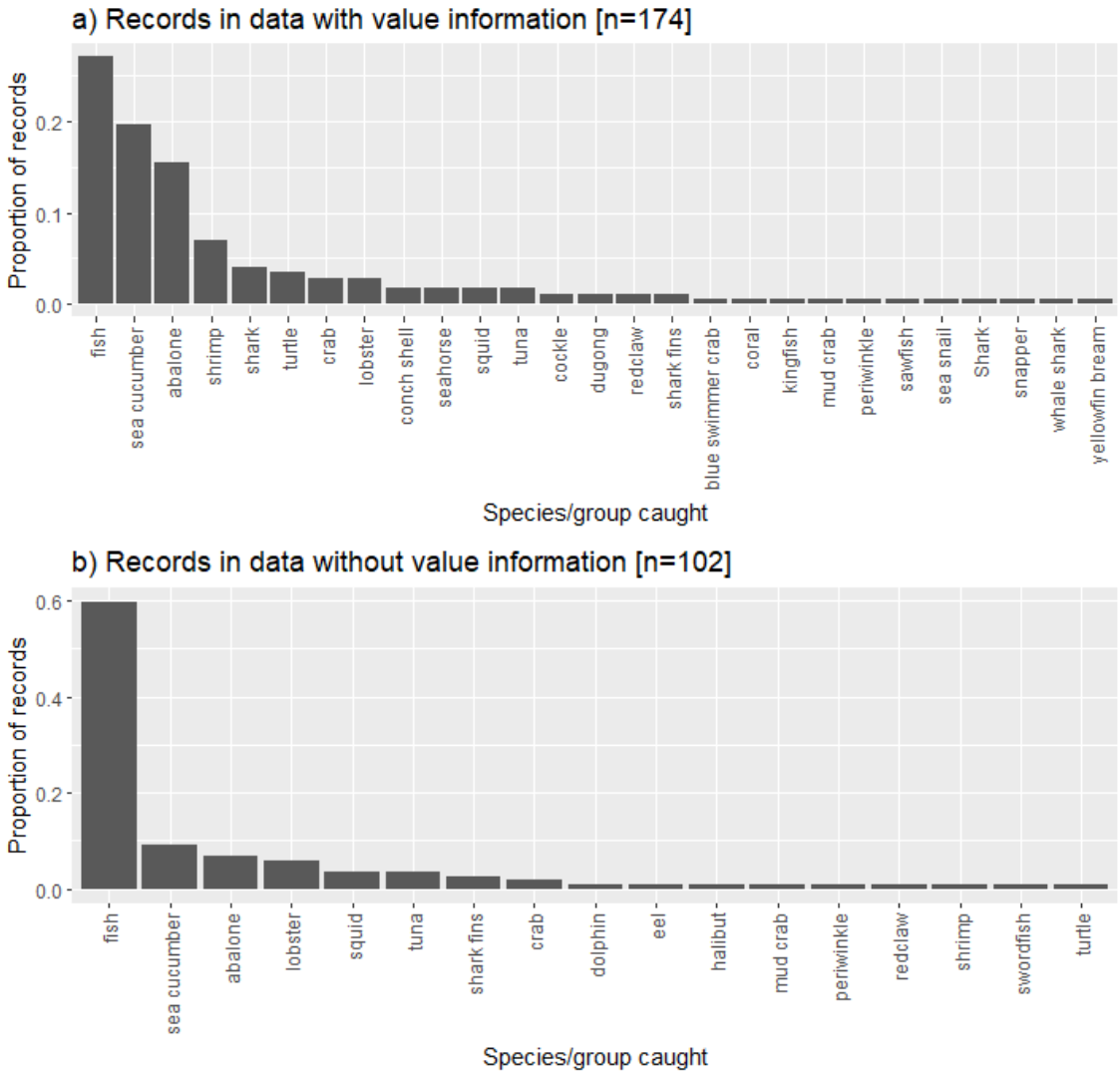

Figure 3 Distribution of the catch of each species in the data set.

2.3.4 Expert interviews

The last source of information is interviews with key experts. The interviews were conducted to obtain information regarding objectives two, three and four of the methodology (see Table 2). For objective two and three, the interviews constitute an additional source of information aside from the surveys and media data, where for objective four the expert interviews are the only source of information. In total, 19 experts were consulted via semi-structured interviews and included professionals active in the fishing industry, governmental as well as non-governmental organizations, academia and independent contractors. The experts interviewed had expertise on the following geographical areas: Mauritius, Sri Lanka, Mozambique, Pakistan, Maldives, South Africa, Somalia, Kenya, Madagascar, Indonesia, Seychelles and the high seas.

To obtain information for objective three, a more in-depth characterization of illegal fishing activities, specific questions were included regarding characteristics such as the most common infraction types and gear types. To fulfill objective four, assessing the efficacy of current governance practices and policies, specific questions were included regarding for example the drivers of IUU fishing and the monitoring, control, and surveillance (MCS) context in the region.

2.4 Analytical approach

In this section, we lay out the analyses conducted to obtain results per objective.

2.4.1 Analyses for objective one, providing an estimate of the volume and value of illegal fishing.

For the **first objective**, which is to acquire an estimate of the volume and value of illegal fishing, we use data from the first question of the survey for fisheries officers. In this question, respondents are asked to select one of six response options for each of the 30 species in the survey: none of the landings in the past 12 months of this species involved illegal fishing activities, or little, less than half, more than half, almost all or all. We refer to those six response categories as ‘scores’ below. We did not use the survey for observers for this first objective because we received fewer responses for this survey, and their survey did not contain the question necessary to calculate the percentages corresponding to their selected scores.

We first use a Bayesian cumulative multinomial logit model (R package: 'brm') to understand what the effect of individual species are on the probability of each of those six response options or 'scores'. Bayesian cumulative multinomial logit models are designed to analyse data in which responses are broken into categories, where the categories have a natural order (e.g., few, some, many). We ran four such models and selected the model with the best predictive capacity. Model one had two fixed effects, one for species and one for region, as well as a random effect for the respondent. Models two and three each included only one fixed effect, for species and region respectively, alongside the random effect for the respondent. The fourth model, or null model assumed all six categories shared a single average value, and only had the random effect for the respondent. All models incorporated a regression weight for each respondent. The regression weights, which range from 1 to 2, represent the quality of that response and thus the importance that should be given to that observation in survey data analysis. They equate to giving each data point an increased or decreased effect on the overall likelihood in the model.

Model 1 was selected as the most predictive model after comparison using leave-one-out cross validation. From that model, we extract the average effect of each individual species on the probability of the six scores (i.e., conditional effect of species on the scores). In figure 4, we present the predicted consensus estimates for the probability of each score of illegal landings (i.e., 'none' (1) to 'all' (6)) for each species.

We use the conditional effect per species on the score to calculate the volume of illegal fishing for that species by computing the percentages that correspond to each score. In Figure 5 you can see the percentages that correspond to each score. We then estimate the volume of illegal catch per species by multiplying the percentages of illegal landings for each species by its indicated probability (Figure 5) and the species total catch volume in the Indian Ocean. The value of this catch was estimated by multiplying the quantity of the catch of each species by its ex-vessel price (data from Sea Around Us, 2019).

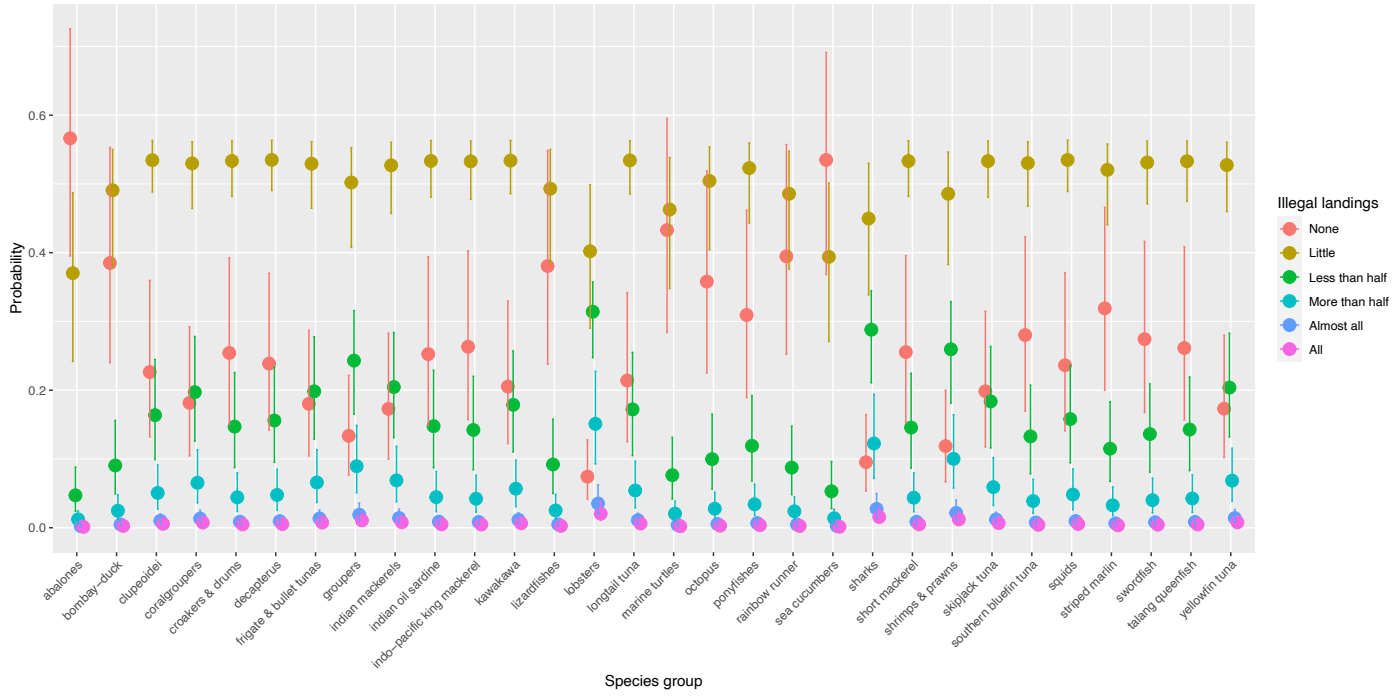

Figure 4 Predicted category of illegal landings for each of the thirty species. The probabilities sum to one and can be directly compared within and across species.

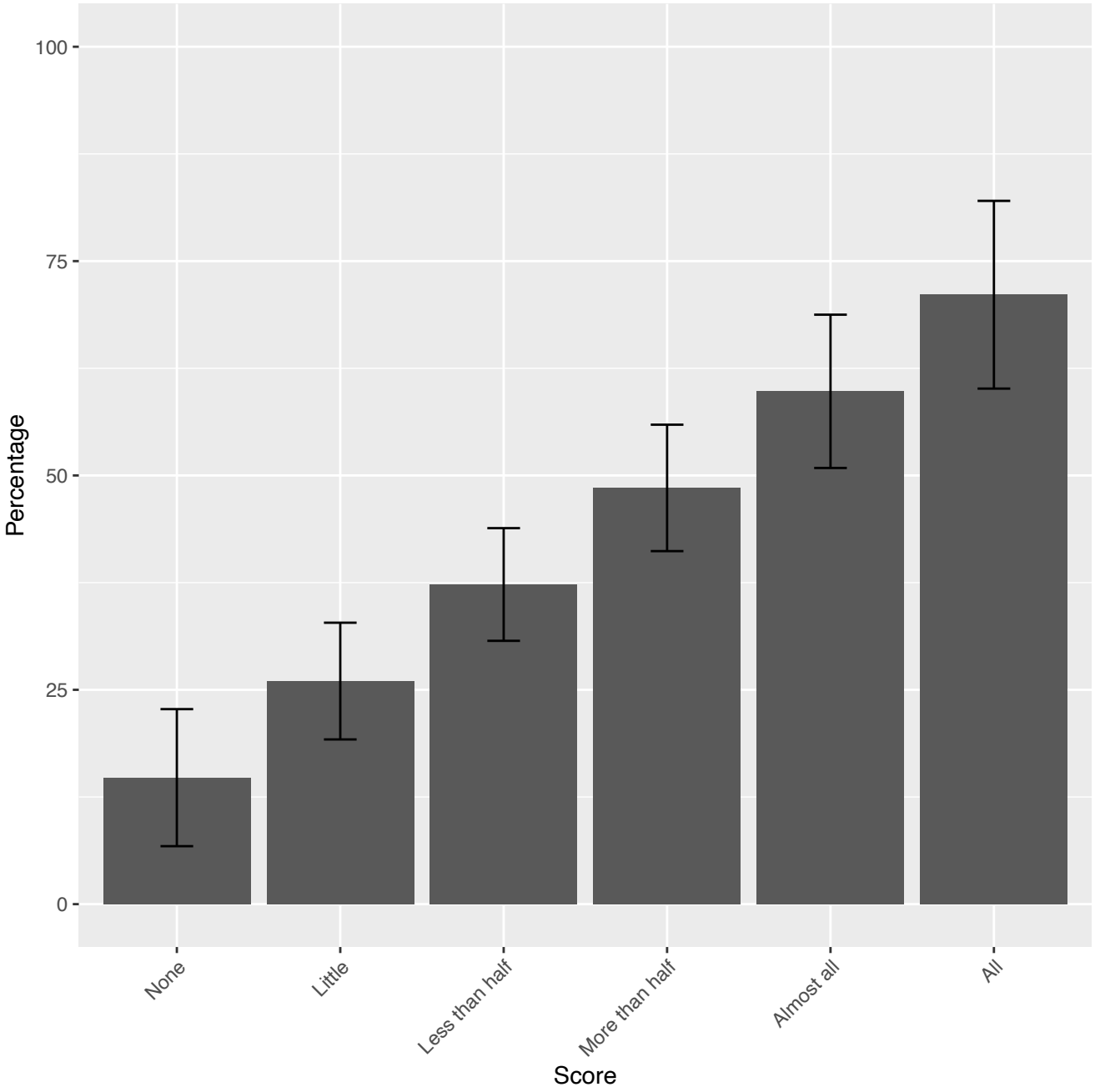

Figure 5 Predicted percentages corresponding to each category. The error bars show the boundaries of the 25th and 75th percentiles of the posterior distributions around the estimates.

Regression tree

Aside from survey data, we use the media data (i.e., the IFED) to expand on estimates and understanding of volume and value of illegal fishing in the region. The approach followed the same methodology as applied in (Wilcox et al., 2021) for the Asia Pacific region. A regression tree was estimated using the data where values were available and applied to the remaining data to predict this value given the known characteristics of the activity.

Regression trees are clustering techniques that group together data with similar characteristics (qualitative or quantitative) and quantitative outcomes based on an analysis of variance (ANOVA). The provide a means of predicting quantitative outcomes in other situations with similar characteristics. They differ from 'normal' regression models in that they do not produce continuous predictions, but instead produce a finite number of possible outcomes (the number depending on the specification of the model). This also allows greater flexibility in the estimation process, as the same functional form does not need to apply at every level of the regression tree. In addition to the previous study by (Wilcox et al., 2021), regression trees have been recently used to estimate drivers of IUU fishing (Welch et al., 2022), incidences of disabled tracking devices (Chand, 2022), poaching in marine reserves (Weekers et al., 2021) and the effects of ghost fishing on marine turtles (Wilcox et al., 2015).

A regression tree was developed using the information available in the 174 reports where catch value could be estimated or was provided directly. The previous study (Wilcox et al., 2021) normalised the estimates of value by the number of vessels, as each incident involved a different number of vessels and this likely affected the total value. However, many reports in this study did not involve fishing vessels per se, as many of the species identified were accessible directly from the beach (e.g., abalone, sea cucumber, lobsters). Information on the number of individuals involved was generally available. Consequently, the dependent variable in the regression tree was the total value of illegal catch per person involved in each incident. The regression tree included the species involved, location of the incident, and the flag of the vessel (or origin of the individuals) involved, and the number of people involved in the indent.

A number of species appeared only once or twice in the data. To develop the regression trees, several species with similar characteristics were grouped together (Table 4b). The value of the IUU catch in each report, however, is based on the species level prices in Table 4a and estimated before aggregation.

Table 4b Species groupings used in the regression tree analysis

Group code in regression tree	Species and species groups included	Notes:
ABL	Abalone	
COC	Cockles, periwinkles	Shore based shellfish combined
CON	Conch Shell	
CRB	Blue Swimmer Crab, Crab, Mud crab, Redclaw	All crabs combined. Also included (rather than with lobster)
COR	Coral (fans)	
DUG	Dugong, dolphins, Whale Shark and turtles	Grouped together as low incidence and not main commercial species
FIN	Shark fins	Shark fins considered separate to shark due to their high value
FSH	Bluenose, Fish, Kingfish, Snapper, Yellowfin Bream	All fish combined in the regression tree
LOB	Lobster	
SCU	Sea Cucumber	
SHO	Seahorse	
SNA	Sea Snail	
SQU	Squid	
SRK	Shark	
PRW	Shrimp, prawns	
SPO	Sponge	
TUN	Tuna, Yellowfin Tuna	
ABL	Abalone	
COC	Cockles, periwinkles	Shore based shellfish combined

The regression tree was derived using the rpart package (Therneau & Atkinson, 2019) in r (R Core Team 2018). The minimum size of any terminal node was set at 5, and the complexity parameter was set at cp=0.000001. This is a very small complexity parameter, the implications of which will be discussed below. However, it provides for a more heterogenous regression tree than higher values of cp would produce.

Several variants of the model were estimated. Using total value rather than value per person provided a slightly better model fit, although this was highly influenced by a small number of large values relating to reporting of cumulative events over a longer time period (e.g., 6 to 12 months) rather than a single incident. Standardising these values by the number of individuals involved compensated for this to a large extent. Increasing the minimum number of observations in each node resulted in fewer nodes and branches but also a substantial decrease in the amount of variation captured by the model.

The derived regression tree is shown in Figure 6, with the data being grouped into 17 nodes from 16 splits. The model captured 34% of the variation in the data (i.e., $R^2 = 0.340$). Unlike predictions from regression models (which estimate the "actual" value of the dependent variable given the independent variables), the regression tree allocates the "average" catch value per person from the observed group within each node to each vessel that meets the criteria for that node (e.g. the country of origin or flag). As a result, goodness of fit measures are generally lower than standard regression models, but may be more appropriate in instances where extrapolation to areas outside the data used to develop the model is required. For example, not all locations/flag/species combinations were available in the data set used to develop the regression tree model, but similarities could be assumed for adjacent regions.

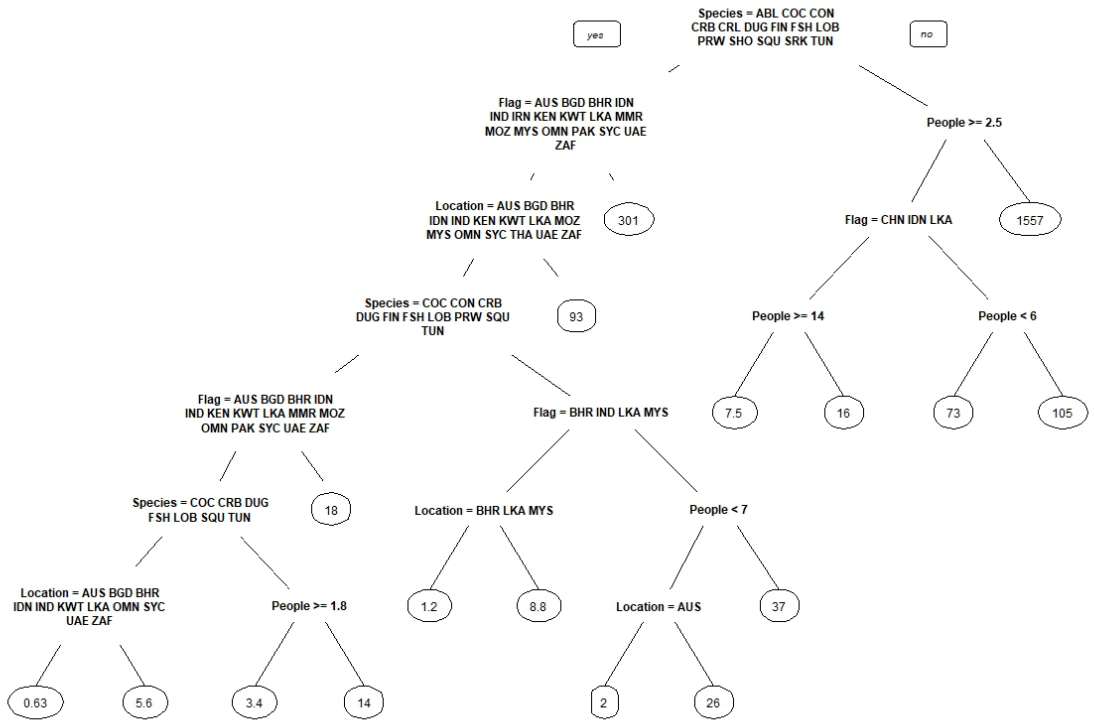

Figure 6 Estimated Regression Tree. Values in the nodes are US$'000 per person.

From the model, the vessel flag or origin of the fishers undertaking the illegal activity and the species targeted were the top two major factor influencing the value of the IUU activity (Figure 6). The average value of the IUU catch per person associated with an IUU media report can be estimated by matching the report characteristics with the splits at each level of the regression tree. For example, media reports involving sea cucumber or sea snails (the first right hand branch) involving one or two people had an average value of catch of US$1.5m each person. The final groupings estimated by the regression tree ranged from US$630 per person (the far left node) to US$1.557m per person (the far right node).

A measure of the relative error at each split of the tree is estimated as a guide to optimal tree size (Figure 7). From this, most of the improvement in model fit is in the first split, based on species caught. The model continued to improve with additional splits up to split 16, although the improvement was small. Despite this, the full model (Figure 6) was retained for the analysis as it provided the greatest flexibility. A sensitivity analysis using a more 'pruned' tree is covered below.

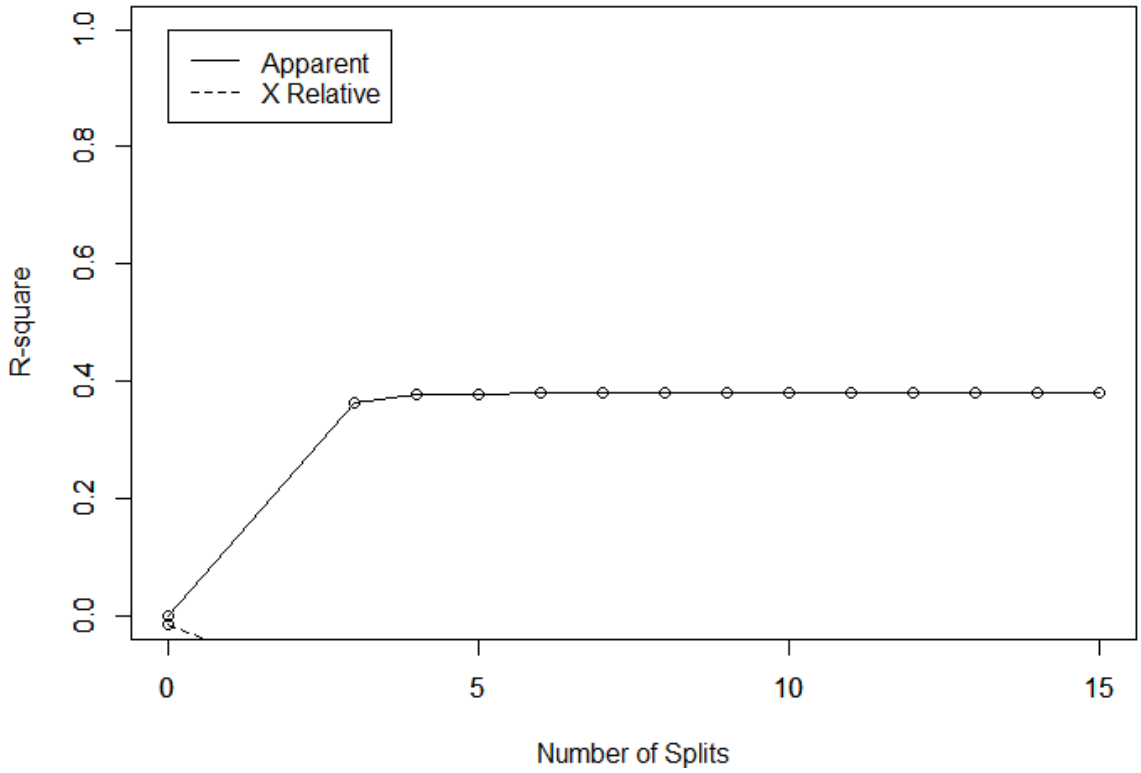

Figure 7 Improvement in model fit with each additional split.

The regression tree in Figure 6 was applied to the remainder of the data (102 observations) to estimate value of the activity based on year, location, flag, species and number of people involved. The species caught was not always specified, so it was estimated based on gear type and what other reports had noted for the same or adjacent location and gear type. The estimated value was then multiplied by the number of people involved to provide an estimate of the total value of the incident.

Sensitivity to the regression tree model

The complexity parameter was set at cp=0.000001 in the base model, which means that the regression tree algorithm would continue to look for branches even if they only resulted in a very small improvement. This is a very small complexity parameter, which may result in model overfitting. However, it provides for a more heterogenous regression tree than higher values of cp would produce. The analysis was also repeated using cp=0.001 and cp=0.01, both of which only resulted in only four nodes (compared with the 17 nodes in the base model). The R^2 also decreased slightly, from 0.34 for the based model to 0.33 and 0.32 for cp=0.001 and cp=0.01 respectively.

While the estimated values from all three analyses were reasonably correlated (i.e., r=0.58 to r=1) (Figure 8), this was largely driven by the high proportion of lower value estimates; all three models were able to produce similar estimates for the low-value records, but the. More restricted models also estimates a greater proportion of high value records (due to the few number of nodes). However, as the complexity decreased (i.e., the value of cp increased), the lower-value estimates were affected and generally overestimated. Given that most records were at the lower-value end of the distribution, there are benefits in using the model with the lowest complexity parameter to better distinguish between these values.

2.4.2 Analyses for objective two, mapping hotspots for illegal fishing

For the **second objective**, i.e., mapping hotspots for illegal fishing across the Indian Ocean basin, we use the survey responses from both fisheries officers and. In both surveys, respondents were asked to identify up to 20 areas they believed to be hotspots of illegal fishing on a map of the Indian Ocean. To address the fact that the number of selected locations varied between respondents (i.e., from 1 - 20) with some respondents concentrating all their selections in a single area while others spread them more widely, we used a Poisson Point Process (PPP) model (Wilcox et al., 2021). The PPP model estimates the distribution of selected locations across respondents and by using this approach, if a respondent clicked many times in a close vicinity, this would yield a similar result to a respondent only providing one selection in that location but selecting no other points (Wilcox et al., 2021). Equal weight was assigned to each respondent, distributed evenly across all the locations selected by that respondent (Wilcox et al., 2021).

Aside from survey data, we use the IFED and interview data to gain further insight into reported locations of illegal fishing. Specifically, we use NER or gazetteers to extract relevant location data from the IFED. During the structured interview, experts were asked whether they had knowledge of more specific geographical locations regarding where illegal acts occur. This additional information complements both the fisheries officer surveys and the media data in informing likely locations of illegal fishing.

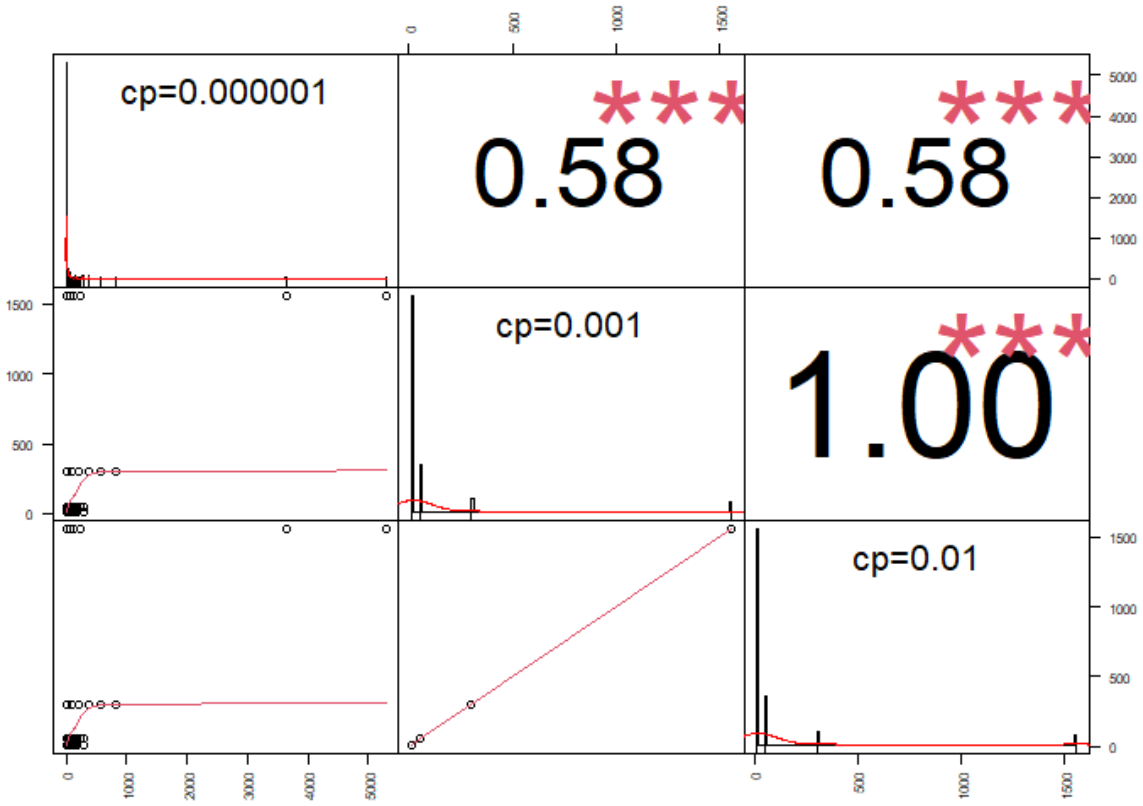

Figure 8 Correlation between estimates using different complexity parameters.

2.4.3 Analyses for objective three, characterizing illegal fishing practices

For the third objective, a more in-depth characterization of illegal fishing, we use data from all sources, i.e., surveys, media data and interviews. More specifically, we use a combination of those data to answer the characteristics of illegal fishing outlined in Table 5. For three characteristics (namely 8, 10 and 12), we used only interviews as a data source. We did not use the survey as a data source for those characteristics due to the high sensitivity of certain questions which could unintentionally incite fisheries officers to exit the survey (such as the involvement of vessel flags) and due to our desire to limit survey length. Additionally, we did not retrieve information on these characteristics in the media data.

Table 5 Characteristics on illegal fishing for which data was collected via one or multiple data sources

	Characteristic	Data source
1	Percentage of yearly catches taken illegally in the respondent's country	Survey for fisheries officers (Q9)
2	The involvement of small versus large-scale vessels in illegal fishing	Survey for fisheries officers (Q10) + Media data + Interviews
3	The types of infractions taking place	Survey for fisheries officers (Q11) + survey for fisheries observers (Q6) + media data + interviews
4	The type of regulations being breached (National, bilateral or international)	Survey for fisheries officers (Q12)
5	The actors & infrastructure involved in illegal fishing activity along the supply chain per species	Survey for fisheries officers (Q13, Q14a-d) + interviews
6	The destination markets for illegally caught fish (local, national or international) per species	Survey for fisheries officers (Q15a-d) + interviews
7	The gear types involved in the illegal activities	Survey for fisheries officers (Q16ad) + Survey for fisheries observers (Q7)+ Media data + Interviews
8	The involvement of different vessel flags	Interviews
9	Species particularly impacted by illegal fishing	Media data + Interviews
10	Ports used to offload illegal catch	Interviews
11	Details on unreported and unregulated fishing as opposed to illegal fishing	Survey for fisheries observers (Q8- Q11) + Interviews
12	Trend of illegal fishing	Interviews

For all results using the survey for fisheries officers and the survey for fisheries observers (Table 5) we use regression models to standardize the result for the quality of the responses. To obtain the most robust results for each characteristic (Table5), multiple generalized additive models (GAMs) were constructed, and the best model was selected based on the Akaike Information Criteria (AIC), with lower AICs representing better fit.

2.4.4 Analyses for objective four, assessing the efficacy of current governance practices and policies

For the fourth objective, an overview of current governance practices and policies, a combination of literature and interviews is used to inform further understanding in current approaches and any gaps. Specifically, during the structured surveys with experts, the following questions were asked to guide discussions to elicit the status in the region:

- What do you think the primary drivers of illegal fishing are in your country/countries of expertise?
- Can you identify recent policies or innovations in place to constrain illegal fishing in your country/countries of expertise?
- What are the primary barriers to tackle illegal fishing in your country/countries of expertise (lack of fisheries data, enforcement capacity, weak policies/law etc.)?
- How important do you think the issue of illegal fishing is in your country/countries of expertise (is it a high priority?)?
- Do you think illegal operators are engaged in other forms of criminal activity in your country/countries of expertise?
- What do you think the impacts are of illegal fishing in your country/countries of expertise?

3 Caveats

When reading the report and interpreting the results, it is important to keep the following caveats in mind.

3.1 Survey audience limitations

First, although we had reasonable coverage of the coastal survey for fisheries officers, we were not able to liaise with all coastal states around the Indian Ocean. Importantly, we did not receive survey results for several important fishing entities in the region. Therefore, these results cannot reflect the region accurately as a whole, but rather an extrapolation of the countries that did participate. For more exact results, increased participation from the coastal states is required.

Second, only limited monitoring takes place in most ports around the Indian Ocean. For that reason, even the fisheries officers we were able to recruit for our survey may not have complete oversight or knowledge of the illegal landings occurring.

Third, it is unknown to what extent each officer can be considered an independent replicate for the purposes of the analyses. Given the close networks in some areas, it is possible that the responses from some respondents are not independent.

3.2 What we intended to measure versus what we have measured

The intent was to estimate illegal landings across the Indian Ocean, and for that we attempted to survey every country adjacent to the Indian Ocean (to ensure the results were representative of the entire region).

We did not manage to obtain responses from all countries around the Indian Ocean, which means our results do not reflect the reality of illegal fishing across the entire Indian Ocean accurately. Particularly the experience and knowledge of fisheries officers from some major catch countries would have been very valuable to gain a more accurate picture of illegal fishing across the region.

Our survey can only make inferences about illegal landings (i.e. not about any illegal discards) and even more specifically, only about illegal landings made across the countries of the Indian ocean we surveyed (so it is possible and likely that total illegal landings are higher because they are not all landed at the countries surveyed, e.g. lots of catch from coastal countries is taken by DWF where we have no survey about proportion of illegal landings made). A useful summary from (Agnew et al., 2009) is helpful here: " Note that the word “landings” is often used to distinguish catches that are retained from catches that are discarded. For simplicity, and to avoid confusion with the suggestion that fish are necessarily landed in the country in whose waters they are caught, we use the word catches here to mean catches that are retained and discards to mean catches that are discarded."

3.3 Landings versus catches

We asked officers about level of illegal landings to calculate the volume and value of illegal fishing across the Indian Ocean. However, there are EEZs where illegal catches are high, yet the catch is not landed in that same EEZ (and potentially not landed in any country adjacent to the Indian Ocean). One case in point is Somalia, where it is well described and confirmed by our expert interviews that much of the illegal catch is landed elsewhere. For that reason, illegal landings of (certain) species in Somalia might have been recorded as relatively low by fisheries officers, while illegal catch of those same species is high.

Moreover, the FAO capture data used to calculate the volume of illegal landings assigns the nationality of the capture data to the flag of the vessel performing the fishing (not to the country where it is landed). This means that fish caught by for example Spain is assigned to Spain regardless of where the catch is landed, and does not allow us to disaggregate between catch volumes landed in countries adjacent to the Indian Ocean and volumes of catch landed elsewhere (though taken from the Indian Ocean).

3.4 Pricing data

There is a significant contrast between the price values associated with different species depending on the data source (i.e., there are differences between the prices derived from the media data and those derived from the ex-vessel price dataset). The prices reported in the media data are generally

higher than those used for the regional analysis, in some cases substantially so (e.g., species such as sea cucumbers and abalone). There are two reasons for the discrepancies. First, the price data used for the survey results represent ex-vessel values, i.e., the prices that fishers receive directly for their catch, or the price at which the catch is sold when it first enters the supply chain (The et al., 2017). Prices increase as seafood gets processed, and it is likely end-of-supply chain values get reported or used in some media data. Second, the ex-vessel price data was averaged out over all countries adjacent to the Indian Ocean with available values for the species in order to obtain one value for the whole of the Indian Ocean. However, ex-vessel values for particular species can vary between countries, for example such as Eritrea and Australia, decreasing the averaged value attached to the species. Prices used for the media analysis, where not derived directly from the media source itself, were, where possible, derived from data specific to the country or immediate region of the media report, and hence may have differed from the average across the entire Indian Ocean region. In other cases, prices were not available from the ex-vessel data base (e.g., turtles, coral, whale shark), but were available from other sources. These species also were not captured in the survey as they were not primarily commercial fish species.

That these prices differ does not impact the overall analysis as the media analysis and survey were undertaken for different purposes. The media analysis was primarily used to estimate the relative contribution to illegal fishing (by value) from domestic or “foreign” fishing vessels in individual countries, as well as provide an indication of the scale and variability of individual illegal events in different countries. In contrast, the survey was used to estimate region-wide values of illegal fishing. The lower prices used in the latter analysis (compared with the media analysis) potentially provide a conservative estimate of this total value.

4 Results

It is important to consider the following information when interpreting the results. First, there were 79 respondents total for the survey for fisheries officers and 23 responses total for the survey for fisheries observers. Second, we did not obtain any survey responses from fisheries officers knowledgeable on subregions 4 or 5 indicated on Figure 2). We had 23 respondents with experience for region 1, 16 respondents with experience for region 2 and 26 respondents with experience for region 3 (14 respondents did not select a region of expertise). Third, not all respondents filled out all survey questions, thus the frequency of responses for each plot varies. We have, however, indicated on all graphs the frequency of responses underlying what is visualized (in, for example, bar graphs you will see the frequency of the answers in the bars). We caution the reader against comparing the results across species, as the number of data underlying the species differ (as indicated by the tables below each species-related figure). Finally, we strongly advise focusing on the totality of data sources and not only the results of the surveys. More specifically, as we use multiple data sources to provide information on different aspects of illegal fishing in the Indian Ocean (i.e., surveys, media data and expert interviews), no single data source alone can provide a holistic picture.

4.1 Estimate of volume and value of illegal fishing

From the survey results, the volume of illegal landings is estimated to be 1,320,921.34 tonnes (27.51% of total landed volume), with an estimated value of USD 1,301,119,802 (roughly 1.3 billion USD). The findings are not based on targeted estimates for subregions 4 and 5 (Figure 2) because no survey responses were recorded for these areas (which does not mean that the total estimate would otherwise be higher, but that now the findings regarding the levels of illegal landings from other subregions are extrapolated to these subregions for which we have no survey responses). The volume of catch included in this estimate amounts to 43.94% of total landings taken in the Indian Ocean.

The estimated volume and value (from the survey results) of illegal landings for each species are shown in Table 6. In terms of the value of illegal landings, shrimps and prawns, and yellowfin tuna represent significant monetary losses for the region.

Table 6 Estimated volume and value of illegal landings for each species. Based on fisheries officers' survey.

Species	Estimated (tonnes) volume	Estimated value (USD)
Abalones	459.8	2,388,014
Bombay-duck	46986	15,827,111
Clupeoidei	112286.2	26,029,406
Coral groupers	363.7	1,592,253
Croakers & drums	75740.8	91,637,441
Decapterus species	64993.3	21,113,062
Frigate & bullet tunas	34210	26,007,326
Groupers	17796	50,969,582
Indian mackerels	94033.5	51,237,853
Indian oil sardines	188841	54,701,245
Indo-Pacific king mackerels	10154.7	6,897,247
Kawakawa	39760	38,669,488
Lizardfishes	23925.8	20,103,382
Lobsters	9726.6	57,442,851
Longtail tunas	36304.3	31,955,227
Marine turtles	0.2	NA
Octopus	8975.6	17,065,286
Ponyfishes	19514.5	22,545,286
Rainbow runners	941.6	1,140,520
Sea cucumbers	1065.3	1,231,883

Sharks	53760.2	55,157,145
Short mackerels	2538.5	1,123,729
Shrimps & prawns	127522.8	289,378,622
Skipjack tunas	154111.3	112,440,636
Southern bluefin tunas	2674.3	9,768,284
Squids	52053.8	80,127,714
Striped marlins	638.7	989,632
Swordfish	7486	17,742,824
Talang queenfish	9627.3	12,259,868
Yellowfin tunas	124429.1	183,576,885

Estimates of the volume and value of illegal fishing from the media data

From the analysis of media data, the distribution of the estimated values associated with each reported incident for each of the locations identified in the media analysis is shown in Table 2. As noted earlier, these are the estimated values of reported incidents and relate to the trip on which they were intercepted; how many other times the vessel engaged in IUU fishing over the year is unknown, as is the number of other vessels or individuals engaging in IUU that were not intercepted. The estimates in Table 7 cover the years 2019 to 2021 and are inflated to 2021 equivalent values.

In many cases, the median value of the catch from an illegal trip was relatively small. Reported incidents with values exceeding US$1m were seen in seven of the locations, with the maximum incident having an estimated value of around $300m (USD). This involved 200 medium-sized vessels (with 1487 individuals) from Somalia caught fishing illegally in South African waters, and is estimated over a year (rather than a single incident). Similar levels of IUU fishing were reported in Somalia also the following year, involving 112 vessels and 832 individuals.

Eighty four percent of the total value across all incidents in the data set was related to unidentified fish species, with squid accounting for around 10% of the total value and sea cucumber around 2% (Figure 9). The remaining 4% of total value was split amongst the remaining species.

Table 7 Distribution of estimates of the value of each reported IUU event, 2019-2021 (USD'000)

Location	Number of records	Mean	Median	Max	Standard deviation
Australia	41	188	3	5029	838
Bahrain	17	38	2	488	119
Bangladesh	9	11	10	33	9
India	36	364	39	3222	714
Indonesia	18	1928	13	32647	7673
Iran	6	1493	882	4861	1828
Iraq	1	686	686	686	*NA*
Jordan	2	301	301	602	425
Kenya	7	4753	74	29089	10827
Kuwait	5	51	26	140	57
Malaysia	27	1402	125	25832	4970
Mozambique	6	35	16	132	48
Namibia	1	4029	4029	4029	*NA*
Oman	10	5	5	15	5
Seychelles	2	5	5	9	7
Somalia	4	98791	37046	300000	134498
South Africa	35	8951	19	300000	50655
Sri Lanka	35	426	54	7268	1250
Thailand	8	95	101	195	69
United Arab Emirates	4	22003	67	87877	43916
Zimbabwe	2	469	469	550	114

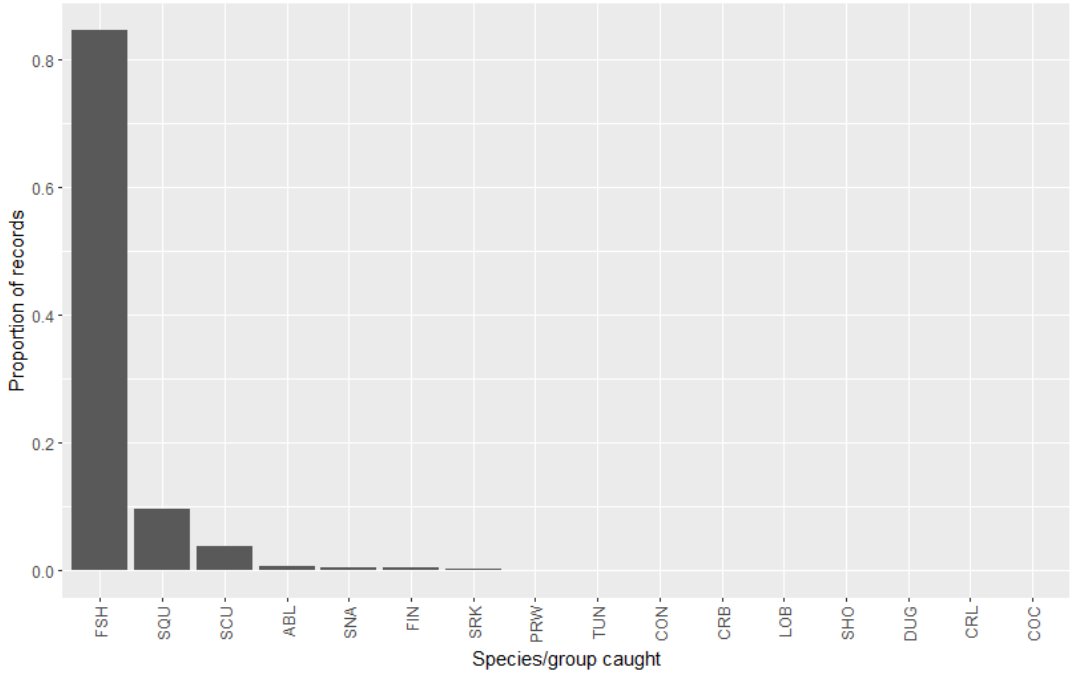

Figure 9 Distribution of IUU catch by estimated value in the complete dataset.

The estimated values were allocated to either the domestic fleet of each country or a foreign fleet based on the flag of the vessel or origin of the individuals (assumed the same when both vessels and number of individuals were identified). For most of the countries examined, illegal fishing by the domestic fleet represented more than 50% of the total reported illegal fishing (by value) (Figure 10).

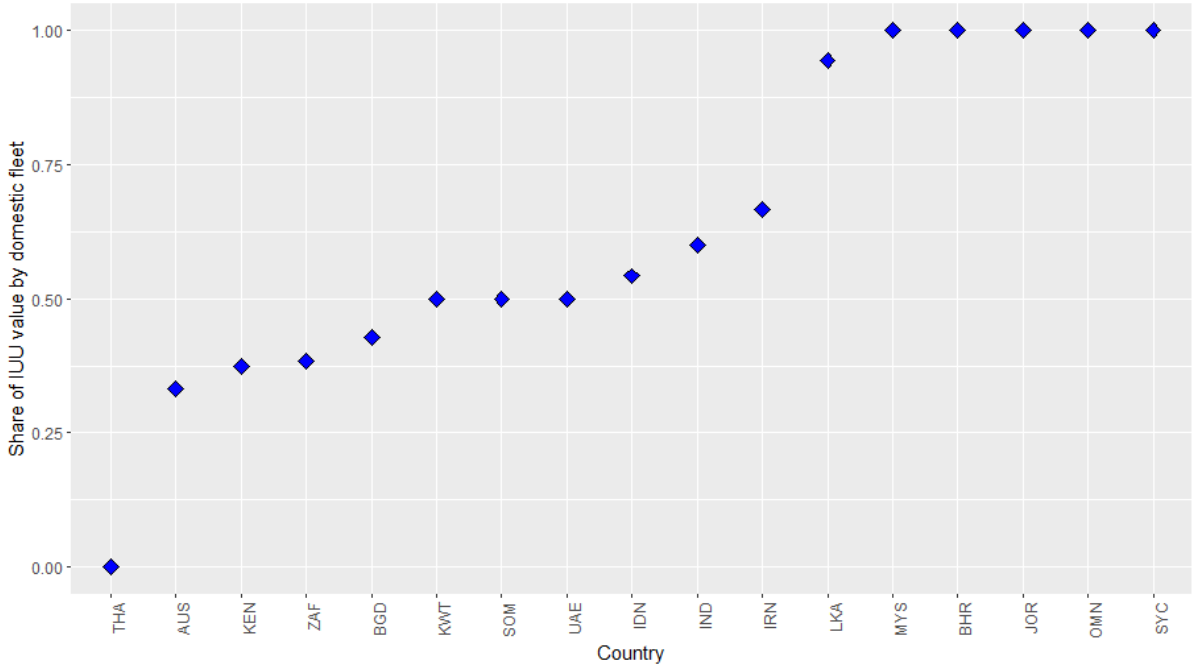

Figure 10 Proportion of IUU fishing undertaken by the domestic fishing fleet.

4.2 Mapping of illegal fishing hotspots

Figure 11 shows the predicted locations of illegal fishing activities across all respondents (fisheries officers as well as observers). We see the highest levels of predicted illegal fishing along the Horn of Africa, into the Gulf of Aden. Other primary hotspots (I.e., locations most commonly identified as areas where illegal fishing activity takes place) are the Bay of Bengal, off the coast of South Africa and around the French Territories. Also, the area surrounding the atolls of the disputed Chagos Archipelago (a marine protected area) is a minor hotspot.

Note: as per 7, Figure 11 is based on survey responses, as such, some areas are underrepresented.

Understanding hotspots of illegal fishing activity was a primary goal of the project. The project allowed for multiple inputs to elicit and understand key hotspots, through each data source used in the project. Information from expert interviews were fundamental in this and suggest that regionally of high priority is continued illegal and unreported fishing within and just outside all EEZs of coastal countries, with poaching and incursions of this nature predominately from DWF flags. Of specific highlight as a hotspot of activity was off the horn of Africa, in the region of Somalia and Djibouti, and the coastal countries off the southwest of the Indian Ocean.

Two other areas of high priority for the region included Robben Island and the Mozambican Channel. Further north, the area between Madagascar and the Seychelles was indicated as a high-risk zone for illegal transshipment.

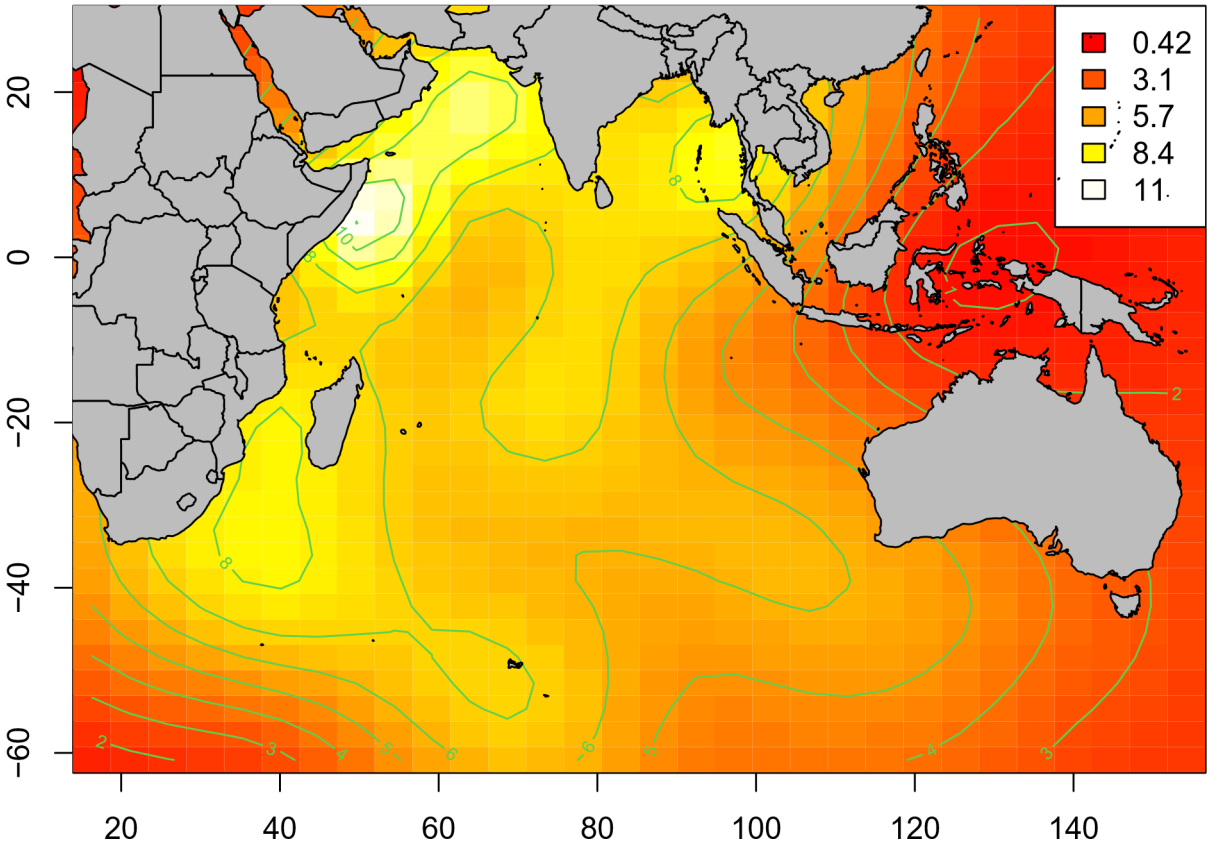

Figure 11 Hotspots of illegal fishing in the Indian Ocean. The legend shows the natural logarithm of the expected number of selections by respondents in a location. Note: some areas might be underrepresented as results do not include all coastal States around the Indian Ocean, including several important fishing entities in the region.

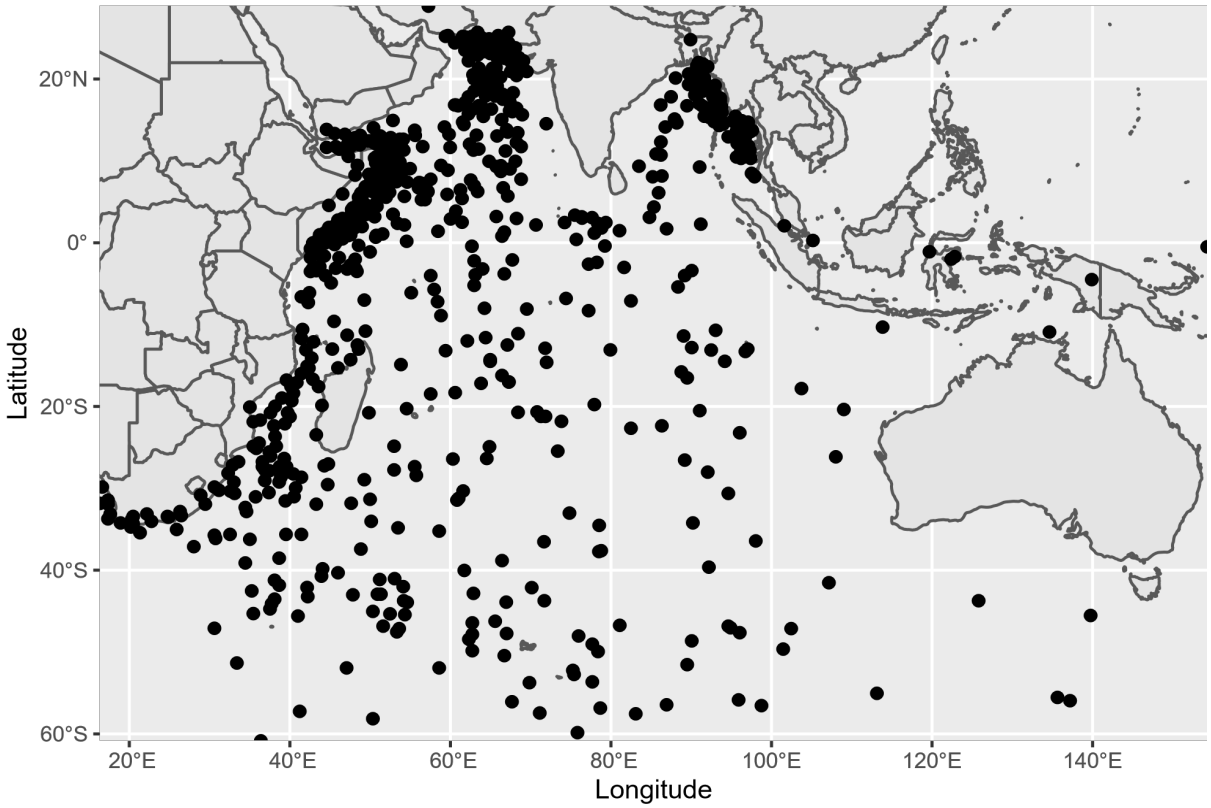

Figure 12 Hotspots of illegal fishing in the Indian Ocean: raw data from surveys.

From the media data, we find that illegal fishing events between the years 2019 and 2022 are most often reported to occur in South Africa and India, followed by Sri Lanka and Malaysia (Figure 13). When looking at the mapped events (Figure 14), we see that the Persian Gulf and the area around India and Sri Lanka come out more strongly as hotspot areas than in the survey for fisheries officers. Few illegal fishing events were mapped to the high seas from the media data, which might reflect lower high seas monitoring activity during the COVID-19 pandemic.

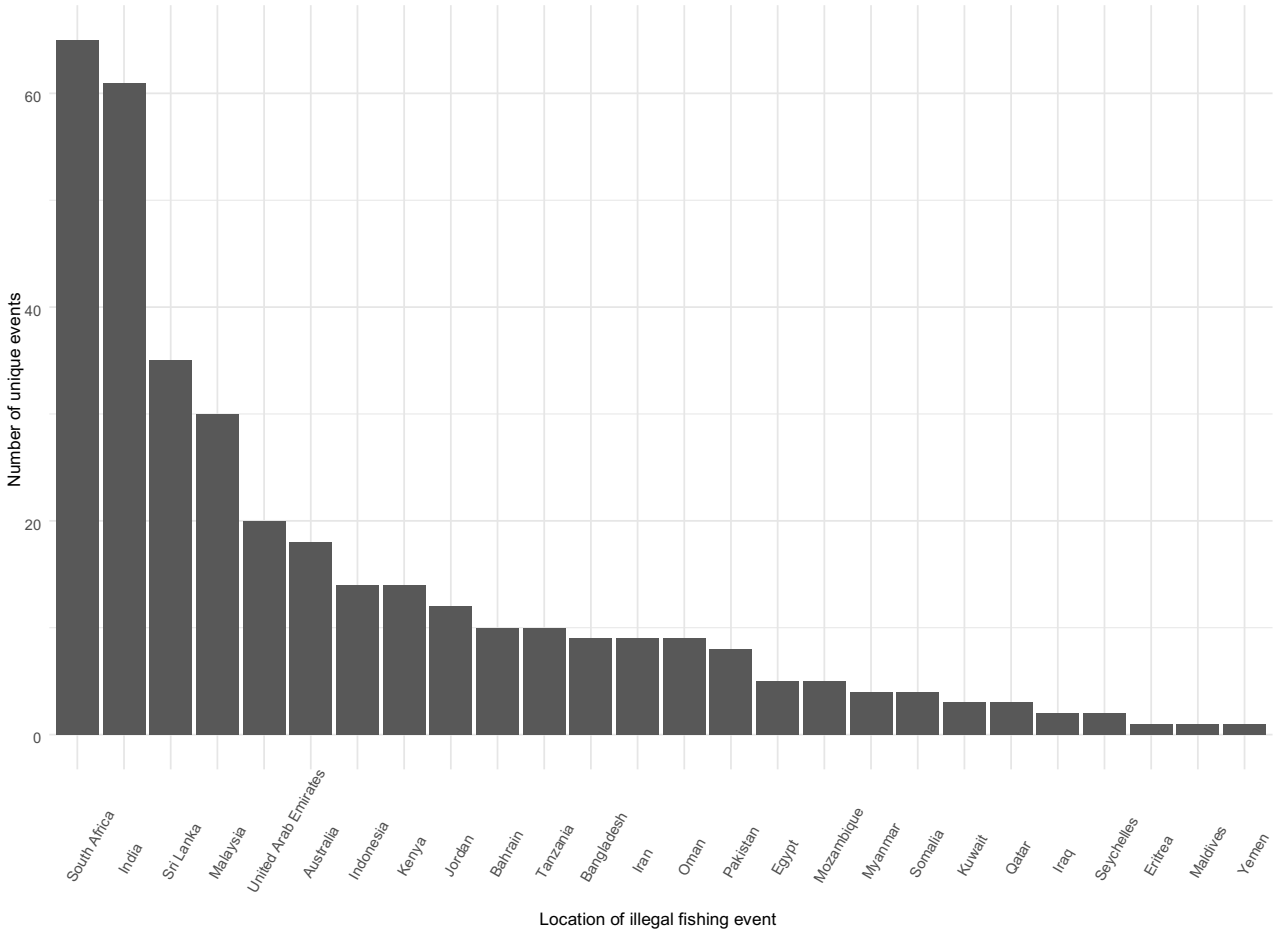

Figure 13 Number of reported locations from media data linked to illegal fishing events for IORA countries (2019-2022)

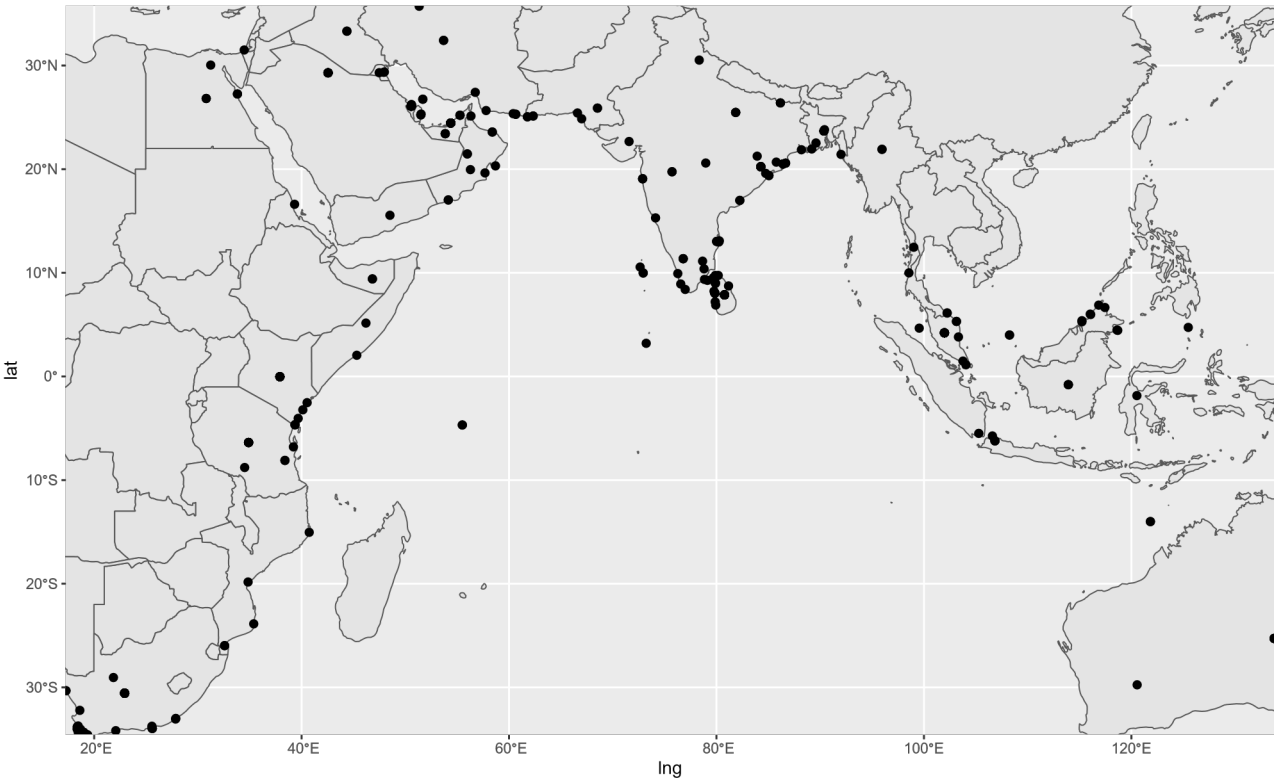

Figure 14 Mapped reported locations from media data of illegal fishing events for IORA countries (2019-2022)

4.3 Characterizing illegal fishing

4.3.1 Percentage of yearly catches taken illegally in the respondent's EEZ, per subregion

Figure 15 shows the predicted proportion of illegal catches in the EEZs of the subregions (see Figure 2) for a subset of species (i.e., the preselected focal species for each region, see table 3, and additional respondent-selected species). All of the species are predicted to be caught illegally primarily in the EEZs of Region 1 (see Figure 2). For abalones, marine turtles and skipjack tuna, Region 3 (see Figure 2) is more strongly represented as a region where illegal catches are made.

Please note that the amount of data underlying each species differs (see Table 8).

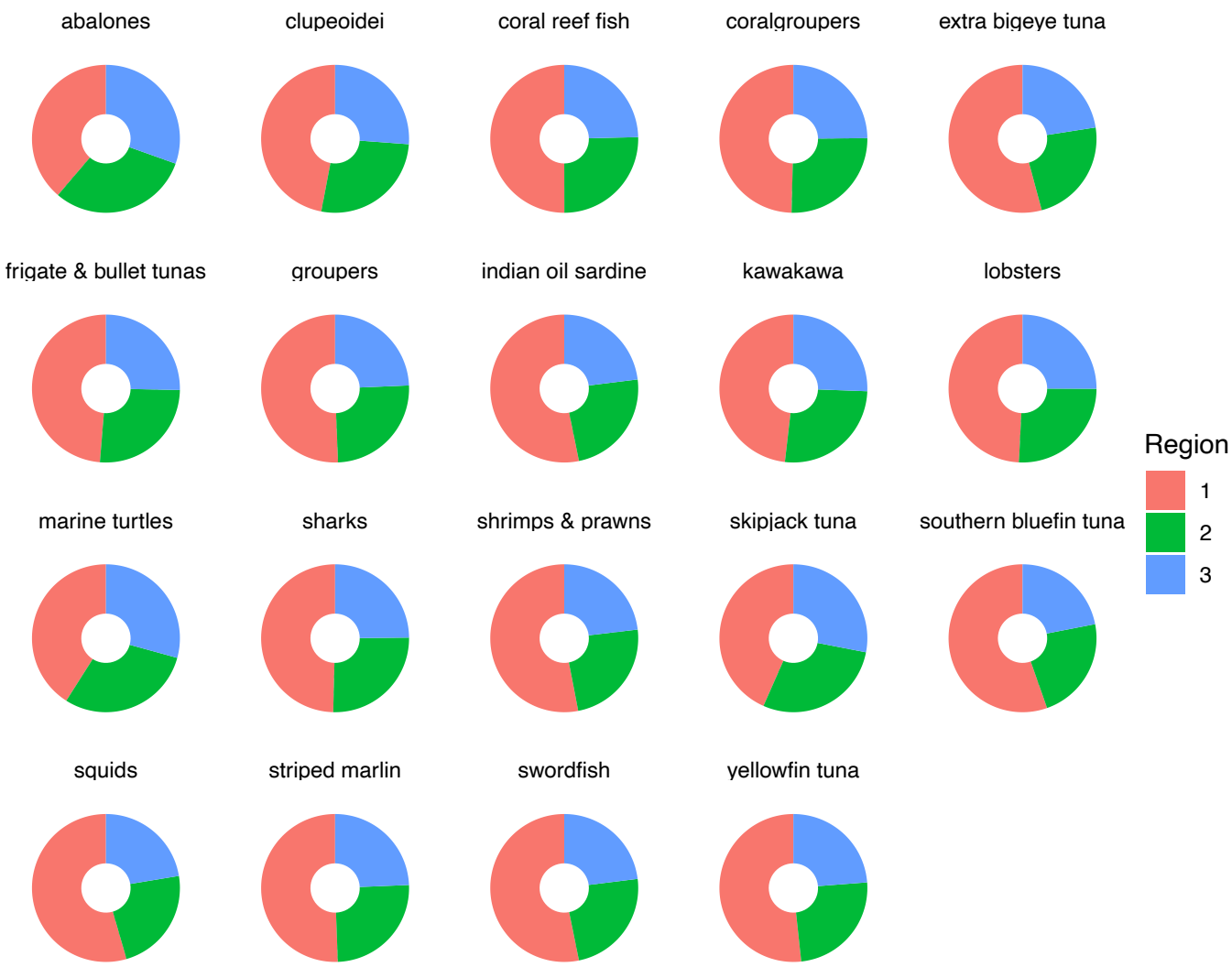

Figure 15 Perceived proportion of illegal catches in the EEZs of the subregions, standardized. If the term 'extra' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Table 8 Number of responses per species for this characteristic. If the term *'Extra'* is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Species	Number of responses
Abalones	2
Coral groupers	5
Clupeoids	3
Coral reef fish	4
Extra bigeye tuna	2
Frigate & bullet tunas	2
Groupers	4
Indian oil sardine	26
Kawakawa	6
Lobsters	14
Marine turtles	4
Southern bluefin tuna	5
Swordfish	3
Shark	43
Shrimps & prawns	3
Squid	16
Skipjack tuna	2
Striped marlin	15
Yellowfin tuna	13

4.3.2 The involvement of small versus large-scale vessels in illegal fishing

Figure 16 shows the relative perceived involvement of small versus large vessels in illegal fishing of the selected species (based on fisheries officer survey). A lower score indicates more involvement from small vessels, whereas a higher score indicates more involvement from large vessels (50% indicates perceived equal involvement of small-and large vessels). Particularly marine turtles and the tunas were perceived to be fished illegally by large vessels. Species such as the Indian oil sardine, shrimps and prawns or coral reef fish were perceived to be fished illegally by small vessels (<12 meters). Please note that the amount of data underlying each species differs (see Table 9).

From the media data, we find that reported illegal fishing events most often reference 'foreign' vessels to be involved in illegal fishing. The second most often reported key word is 'industrial', which can refer to both domestic and foreign vessels (Figure 17).

From expert interviews, industrial, semi-industrial and even artisanal vessels were all perceived to be involved with illegal fishing activities. However, result from our expert interviews suggested larger vessels over 20 metres were more likely to be perceived as illegally fishing in the EEZs of coastal states including Seychelles, Somalia and Kenya. These vessels had been identified or perceived to be trawlers or foreign vessels from Asiatic countries. However, while medium or smaller vessels may also be illegally fishing in these areas it was suggested they were not subject to the same level of monitoring as larger vessels.

Interviewees believed that this was due in part to a lack of global and regional attention on illegal activities by smaller vessels. Inadequate monitoring of small vessels is a concern for countries with small-scale fisheries in an open access system, as it may lead to over-exploitation. The impact of illegal fishing according to vessel size was also raised by interviewees. Artisanal vessels were perceived as having a lesser impact compared to industrial vessel activities.

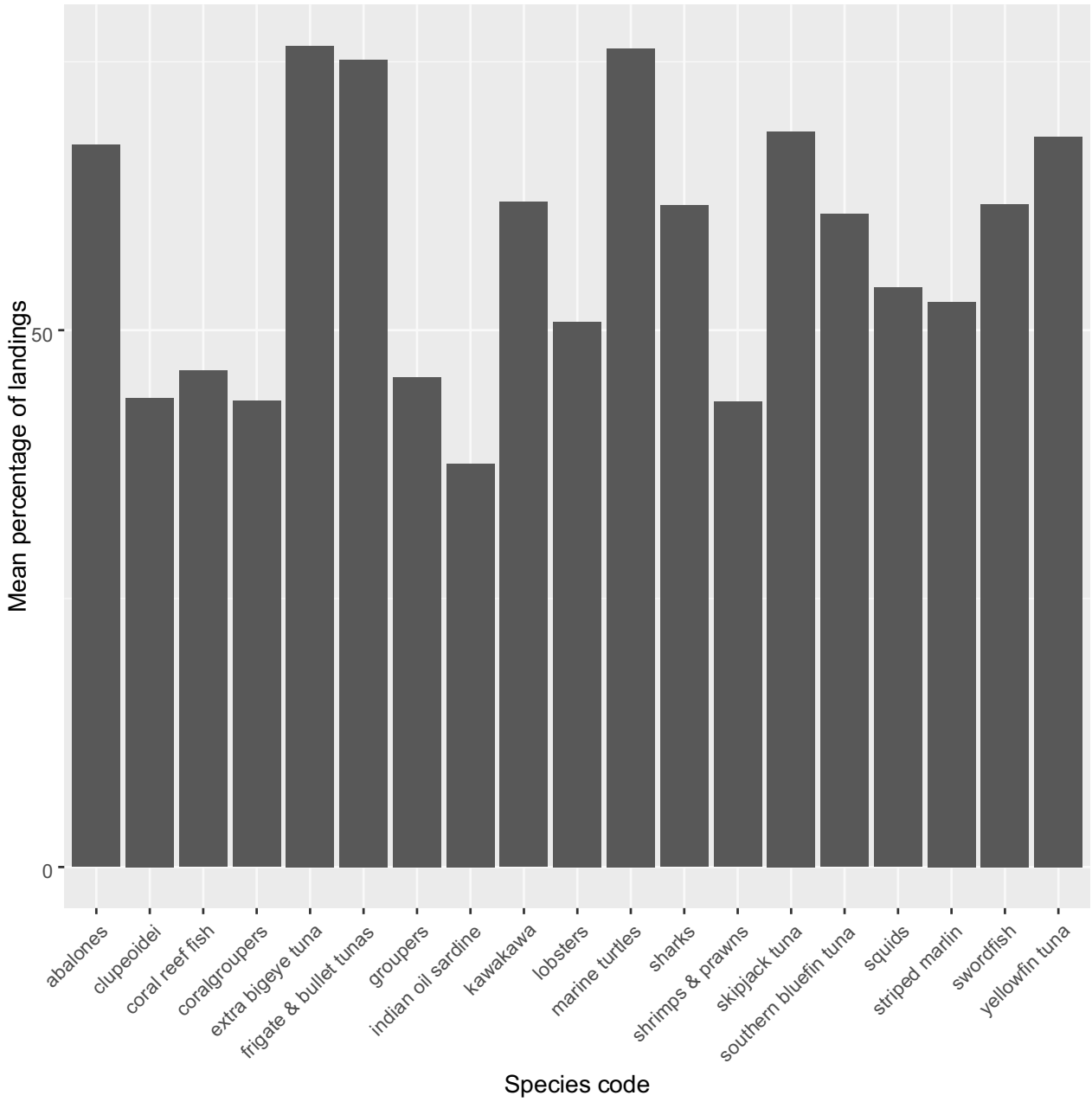

Figure 16 Perceived involvement of small versus large vessels in illegal fishing of the selected species (based on fisheries officer survey). A lower score indicates more involvement from small vessels, whereas a higher score indicates more involvement from large vessels (50% indicates perceived equal involvement of small-and large vessels). If the term 'extra' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

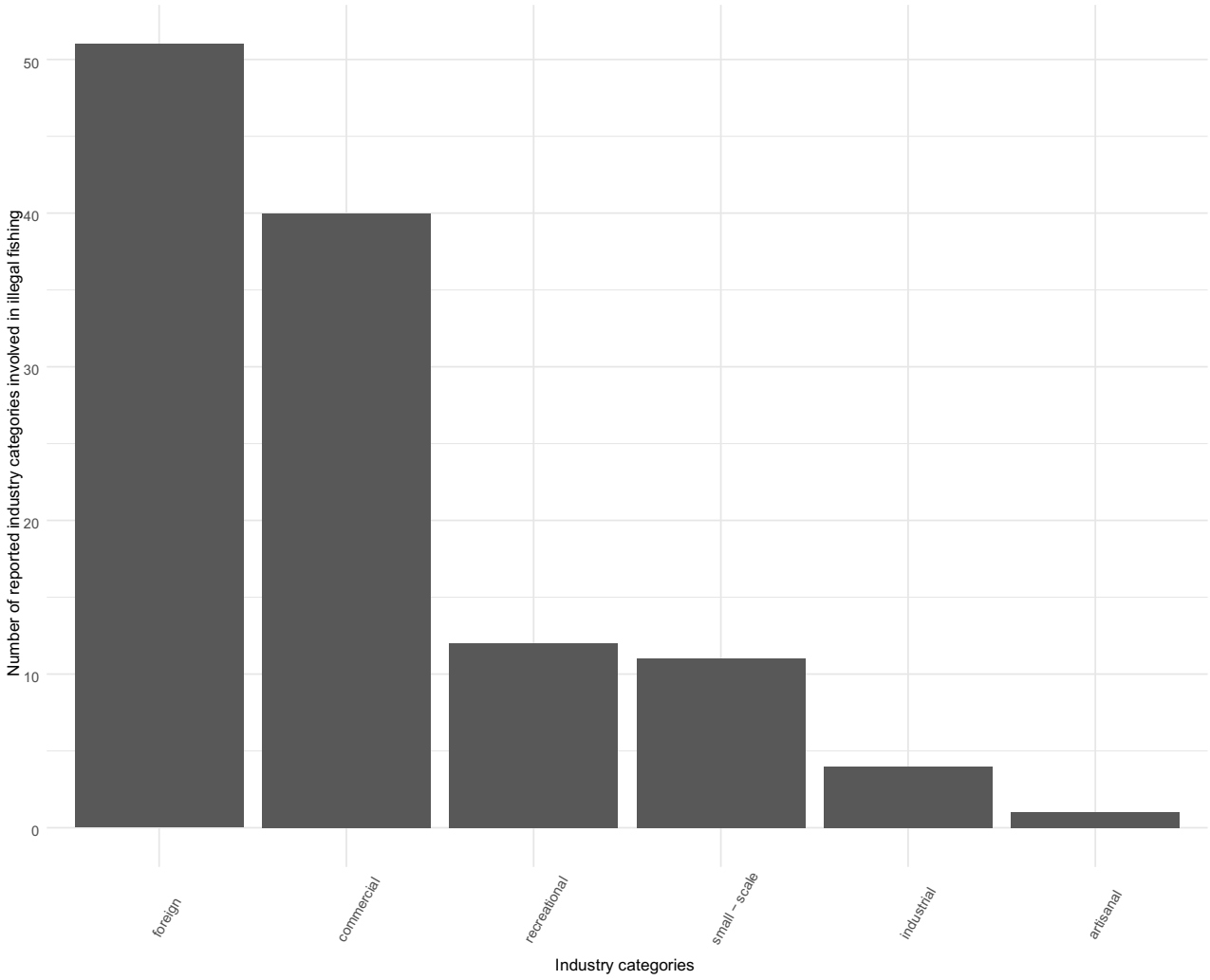

Figure 17 Number of reported key terms related to industry types in the media data.

Table 9 Number of answers per species for this characteristic of perceived involvement of small versus large vessels. If the term '*Extra*' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Species	Number of responses
Abalones	2
Coral groupers	5
Clupeoids	4
Coral reef fish	5
Extra bigeye tuna	2
Frigate & bullet tunas	2
Groupers	4
Indian oil sardine	25

Kawakawa	6
Lobsters	13
Marine turtles	3
Southern bluefin tuna	7
Swordfish	2
Shark	42
Shrimps & prawns	2
Squid	18
Skipjack tuna	2
Striped marlin	13
Yellowfin tuna	14

4.3.3 The types of violations taking place

Figures 18 and 19 show the perceived involvement of large and small vessels in a number of different illegal fishing activities. Particularly the use of unauthorized gear and the fishing for undersized or protected species was perceived by fisheries officers to involve small vessels more often. From the survey for fisheries observers however, a less clear pattern emerges. The results indicate that no infraction is judged by the observers to be more prevalent on the high seas, as there were no meaningful differences between the different infractions (e.g., fishing during a closed season or unauthorized transshipment) in terms of how often they occur.

From the media data, we also find that fishing for undersized or protected species are the most reported infraction (see Figure 20).

Results from our expert interviews suggested a range of illegal activities occurring in EEZs and in areas beyond national jurisdiction by both industrial and semi-industrial vessels. Illegal and unauthorised fishing gear was identified as a key problem including the use of trawling and monofilament nets, FADs and dynamite fishing. Unauthorised driftnet fisheries (up to 15km) were highlighted as an issue in the Northern Arabian Gulf, while dynamite fishing in areas close to shore was identified as a concern for countries such as Kenya, Tanzania and Mozambique. Other illegal activities include fishing for species without a license or permit, fishing in closed and prohibited spaces or non-compliance to MCS requirements such as lack of VMS and faulty or forged documents.

The interviewees also raised broad concerns about the illegal bycatch and discarding of species, such as shark and tuna, by industrial and foreign vessels including European and Asian longliner fleets. Finally, illegal transhipment was identified as occurring to the north of Madagascar and Mauritius.

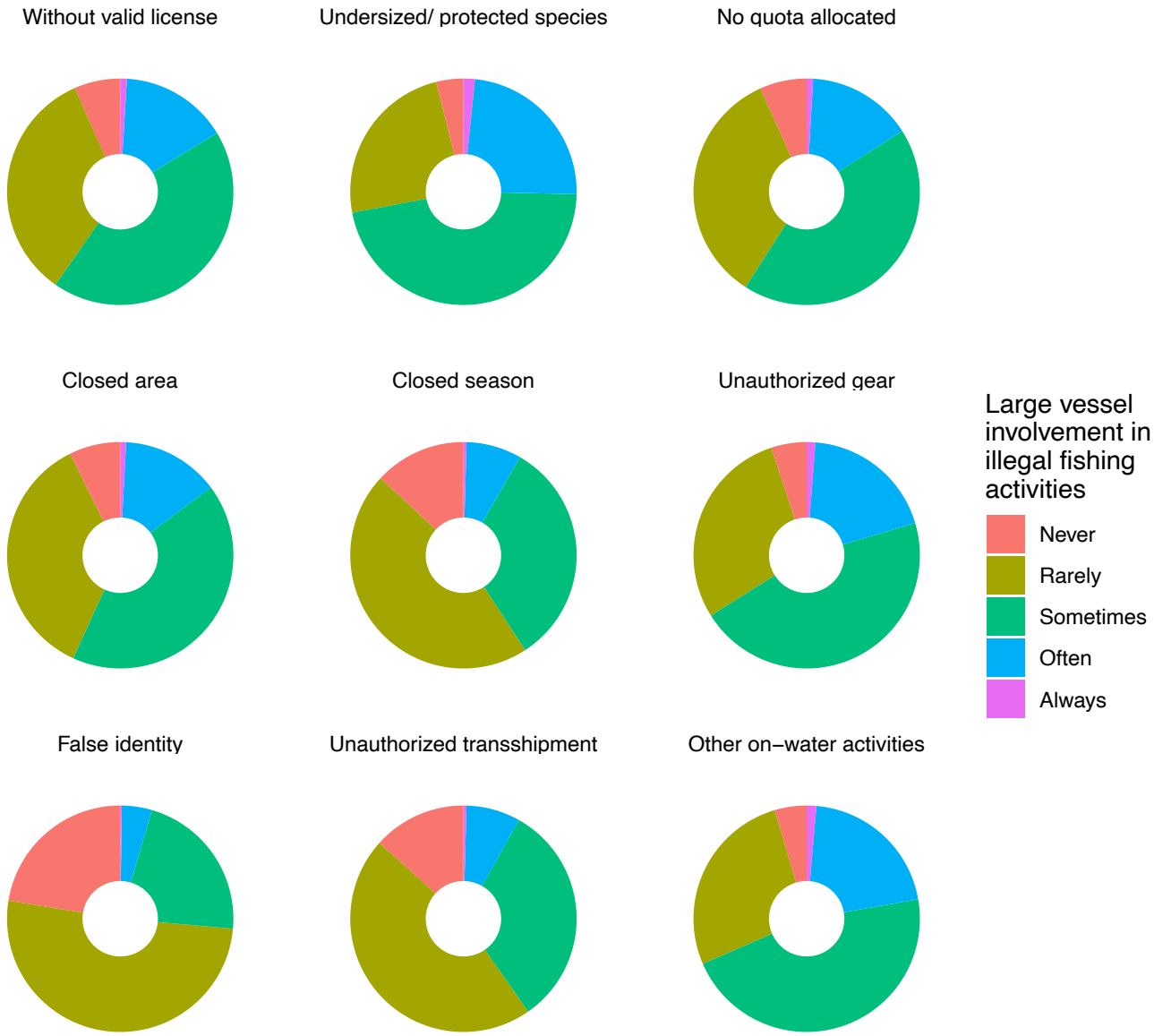

Figure 18 Perceived probability of involvement of large vessels in a number of illegal fishing activities (based on fisheries officer survey).

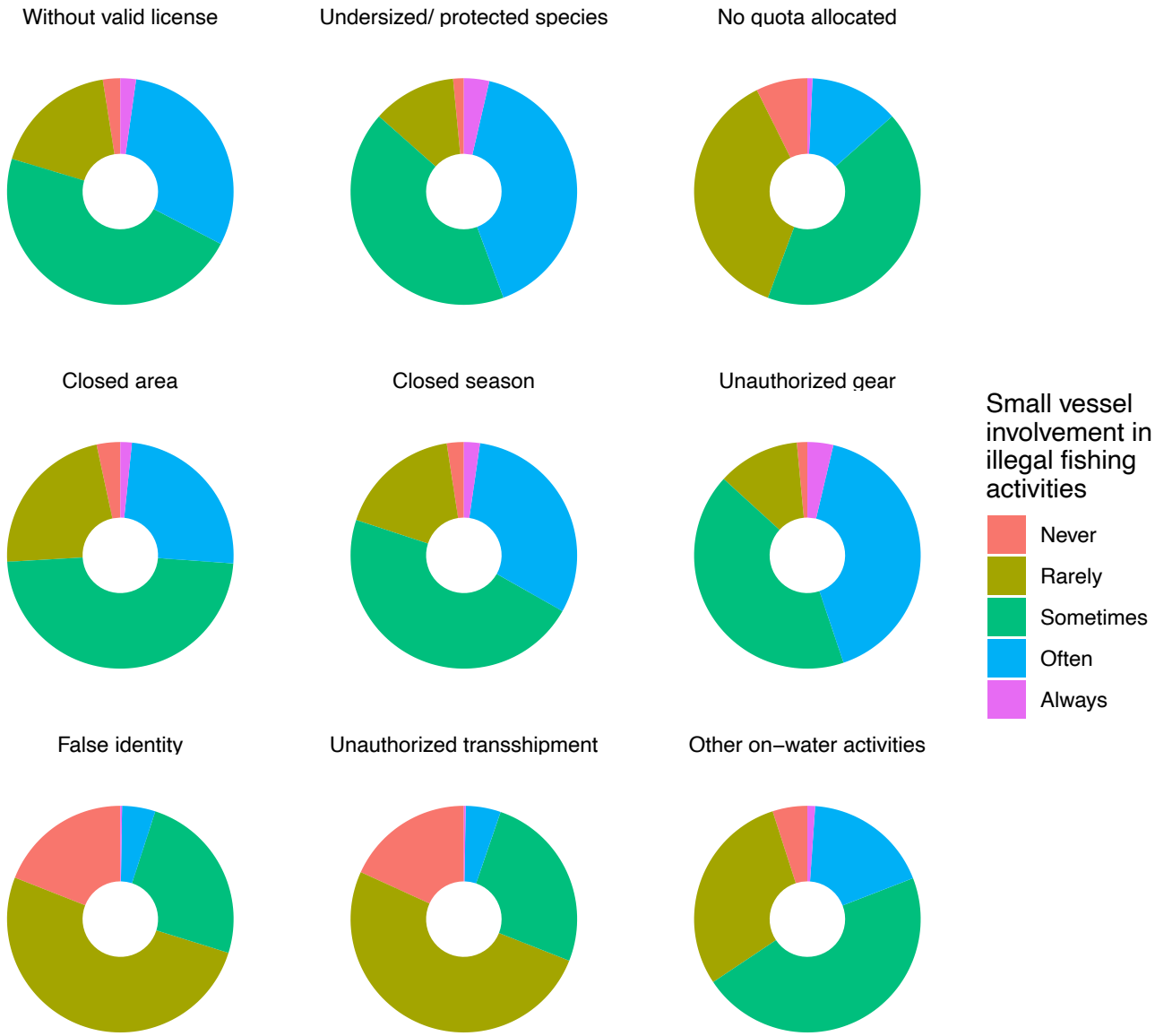

Figure 19 Perceived probability of involvement of small vessels in a number of illegal fishing activities (based on fisheries officer survey).

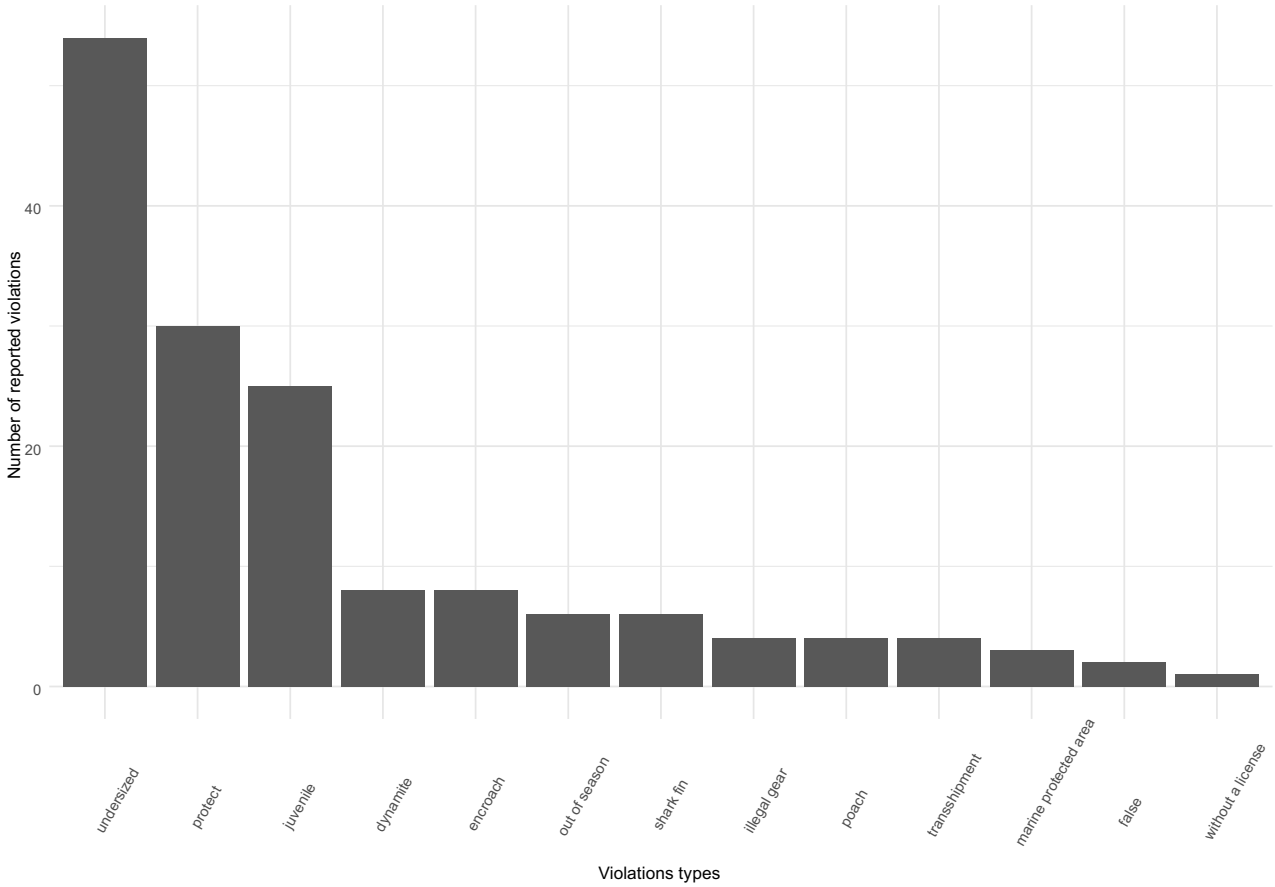

Figure 20 Reported violations across the Indian Ocean in the media data (2019-2022).

4.3.4 The type of regulations being breached

Figure 21 shows the regulations officers believed are being breached in their region for a subset of species (i.e., national, bilateral, or international regulations; or unknown). For most species, primarily national regulations were thought to be breached. However, international regulations were perceived to be transgressed for swordfish, bigeye tuna and skipjack tuna.

Please note that the amount of data underlying each species differs (see Table 10).

Figure 21 Regulations perceived as being breached (based on fisheries officer survey). N = national, B = bilateral, I = international and U = unknown. If the term 'extra' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Table 10 Number of answers per species for this characteristic. If the term '*Extra*' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Species	Number of responses
Coral groupers	5
Clupeoids	5
Coral reef fish	5
Extra bigeye tuna	2
Frigate & bullet tunas	2
Groupers	3
Indian oil sardine	27
Kawakawa	6
Lobsters	10
Marine turtles	4
Southern bluefin tuna	6
Swordfish	2
Shark	41
Shrimps &prawns	3
Squid	18
Skipjack tuna	2
Striped marlin	13
Yellowfin tuna	15

4.3.5 The actors and infrastructure involved in illegal fishing activity along the supply chain

Figure 22 depicts the actors perceived to be involved in illegal activities for a subset of species. Primarily fishers were thought to be involved in illegal activities, though for swordfish and abalones other actors were perceived to be near-equally involved. Second to fishers, purchasers were most often perceived to be involved in illegal activities.

Please note that the amount of data underlying each species differs (see Table 11).

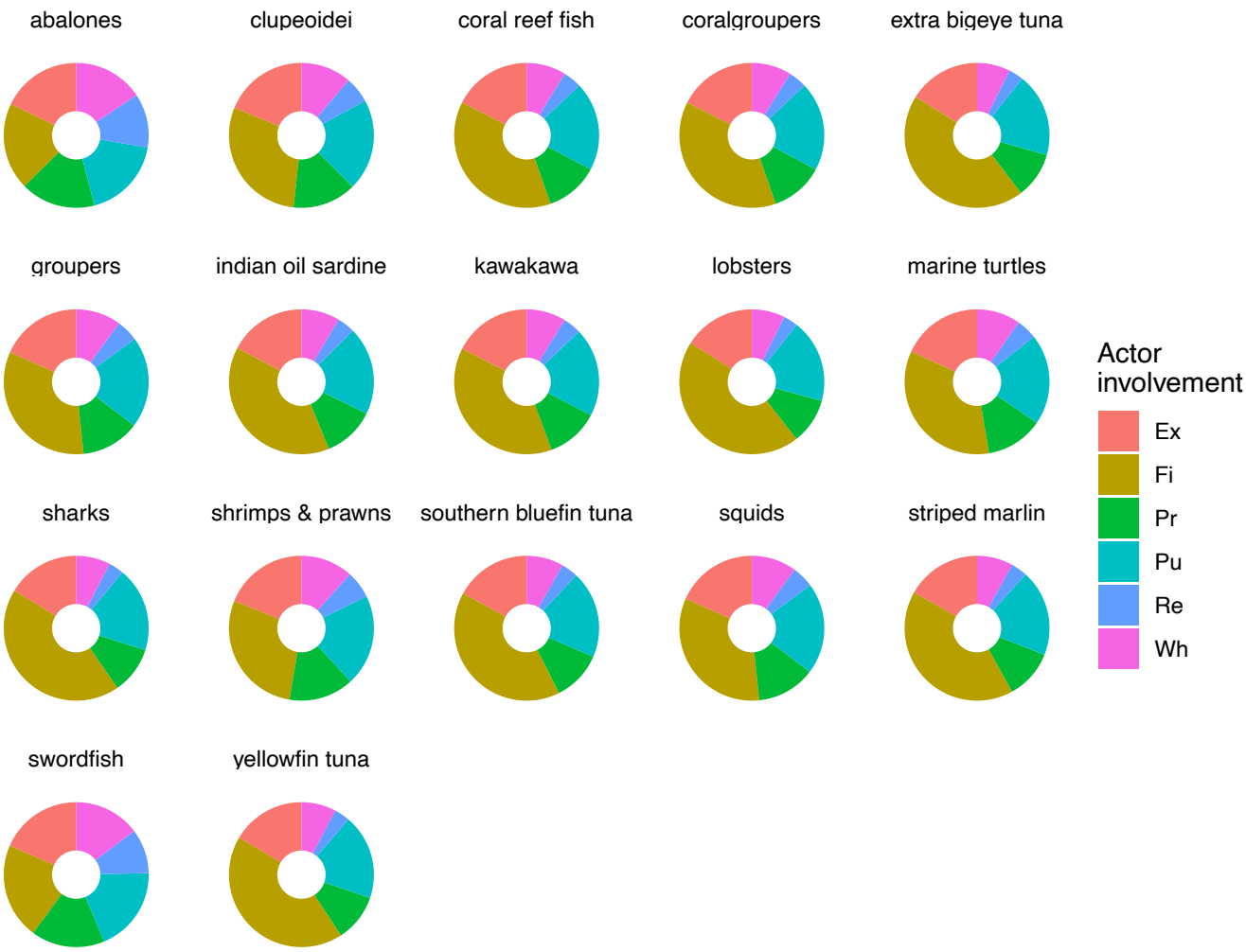

Figure 22 Actors perceived to be involved in illegal activities (based on fisheries officer survey). Ex = exporter, Fi = fisher, Pr = processor, Pu = purchaser, Re = retailer and Wh = wholesaler. If the term 'extra' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Table 11 Number of answers per species for this characteristic. If the term '*Extra*' is placed in front of a species name, it denotes that the species was nominated by participants as it was deemed of particular importance (not otherwise present in the list of 30 species in the survey).

Species	Number of responses
Abalones	2
Coral groupers	3
Clupeoids	5
Coral reef fish	4
Extra bigeye tuna	2
Groupers	2
Indian oil sardine	14
Kawakawa	4
Lobsters	10
Marine turtles	4
Southern bluefin tuna	4
Swordfish	2
Shark	32
Shrimps &prawns	3
Squid	13
Striped marlin	11
Yellowfin tuna	9

Regarding infrastructure, fishing boats are perceived the most likely to be involved in illegal activities by far, markets second, and exporters and transshipment boats third (Figure 23). Restaurants were seen as the least likely infrastructure involved in illegality. The results remained fairly stable across species, except for skipjack tuna, where respondents considered all infrastructures to be likely involved in illegal activities.

The role of agents in the facilitation of illegal fishing was a clear theme that emerged from our expert interviews in relation to actors and infrastructure. It was suggested that representatives, primarily from foreign fishing countries, are often based in coastal states and will engage in criminal activities

to ensure illegally caught fish moves through the supply chain. Examples included the concept of a 'king-pin' agent that uses bribes to help fishers and other actors involved avoid legal penalties. However, the role and extent of influence of these agents remains unclear.

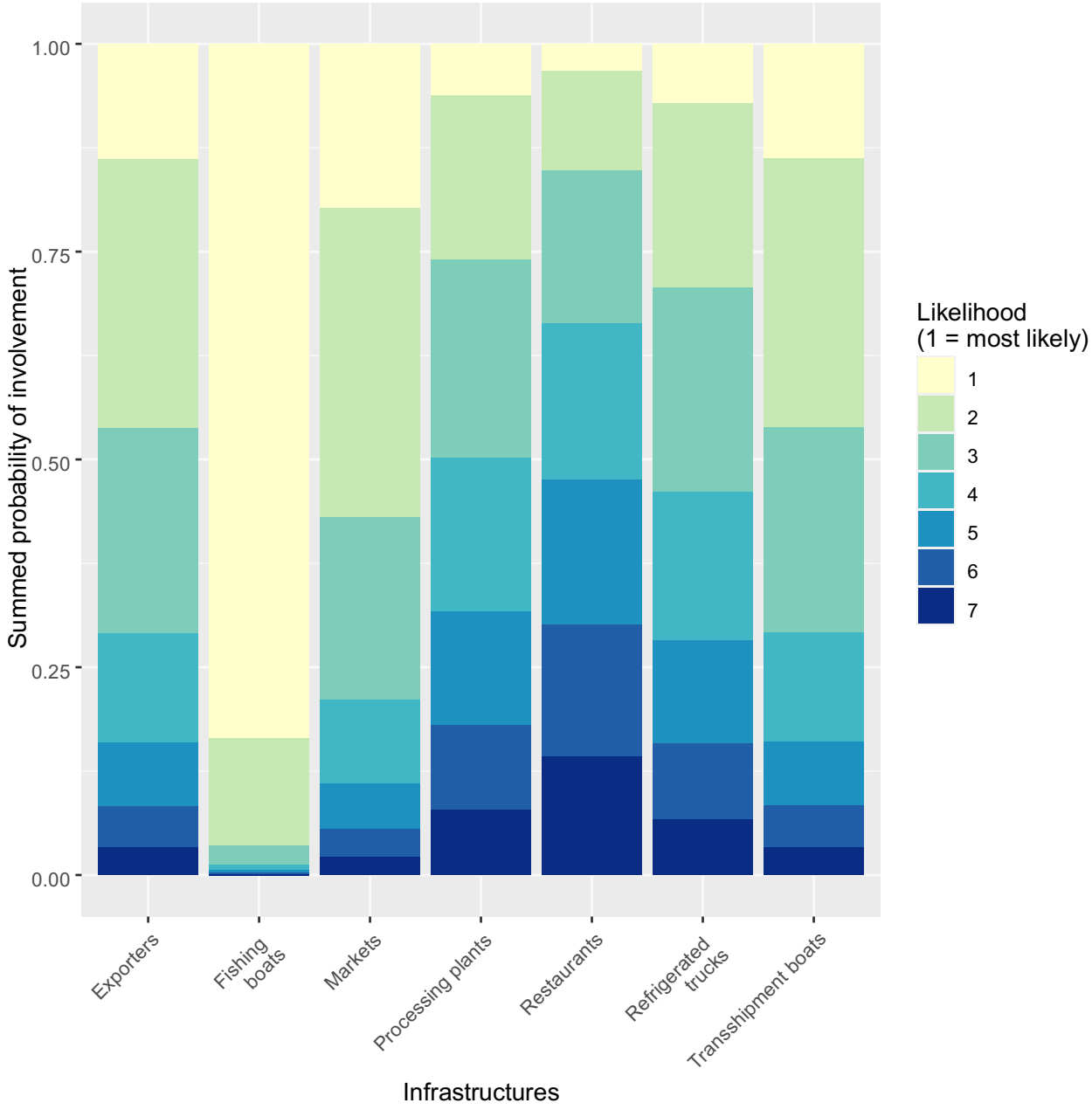

Figure 23 Infrastructures perceived to be involved in illegal activities (based on fisheries officer survey).

4.3.6 The destination markets for illegally caught fish

Local markets are the most likely destination for illegally caught fish according to fishery officers, and international markets the least likely (Figure 24). The destination market for illegal fish did not vary significantly across species.

According to the results from the expert interviews, illegal fish caught by all types of vessels will often stay in the local market. It is suggested that all illegal catch caught by small-scale artisanal fishers will be sold locally but illegal catch from commercial vessels will likely be distributed globally. One example suggests that tuna, often caught with illegal driftnets, is being exported to countries in Europe, Asia, the Middle East and the United States while bluefin tuna specifically is being exported to China and Japan. Interviewees suggested that Hong Kong was a key market for shark fin while shark carcasses, including Mako and Blue, were being shipped to Europe.

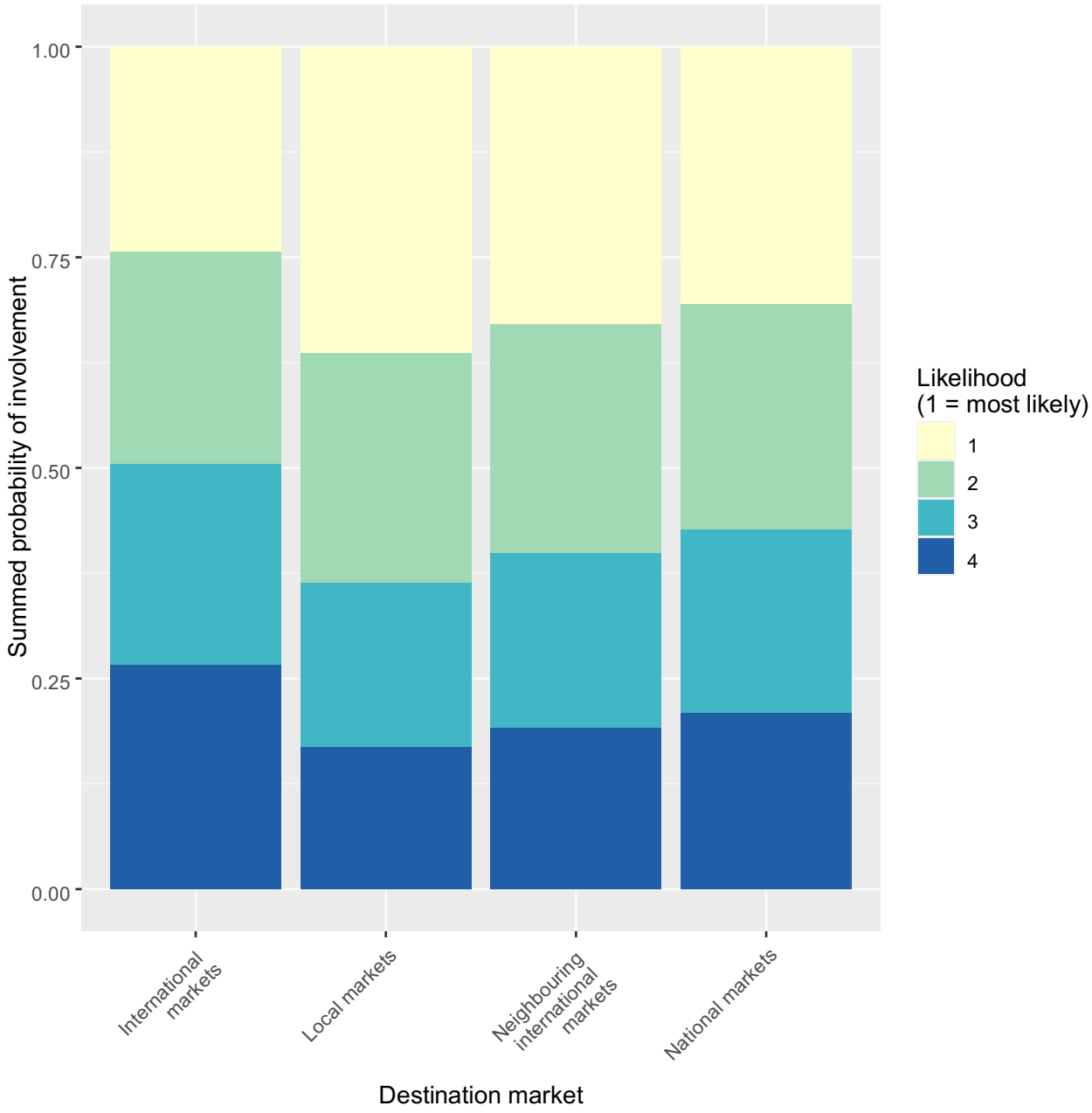

Figure 24 Perceived most and least likely destination markets for illegally landed fish (based on fisheries officer survey). 1 = most likely market where illegal fish ends up, 4 = least likely.

4.3.7 The gear types involved in the illegal activities

According to the fisheries officers, trawlers have the highest likelihood to be involved in illegal fishing activities. The results from the media articles reinforce this finding, as trawlers were the most reported gear type to be involved in the illegal fishing events (Figure 27). Both purse seiners and set gillnets were also identified (Figure 25).

Fisheries observers were asked, for each gear type, whether the gear was 'Never', 'Once in a while', 'About half the time', 'Most of the time', or 'Always' involved in illegal activity. From that, we can see that on the high seas, all gear types except for three were most probable to be involved in illegal fishing *once in a while*. The three exceptions are drifting longlines, set gillnets and set longlines, which were most probable to be involved in illegal fishing about half the time (Figure 26). Additionally, observers were also asked how often reefers, bunkers and support vessels are involved in illegal fishing activities; the perceived probability for all those vessel types is 20.2 %.

Results from our expert interviews suggest concerns for the role and frequency of supply vessels and their use of FADs. It was noted that FADs can be activated and deactivated from vessels or even ports and there is limited oversight or regulation over their use.

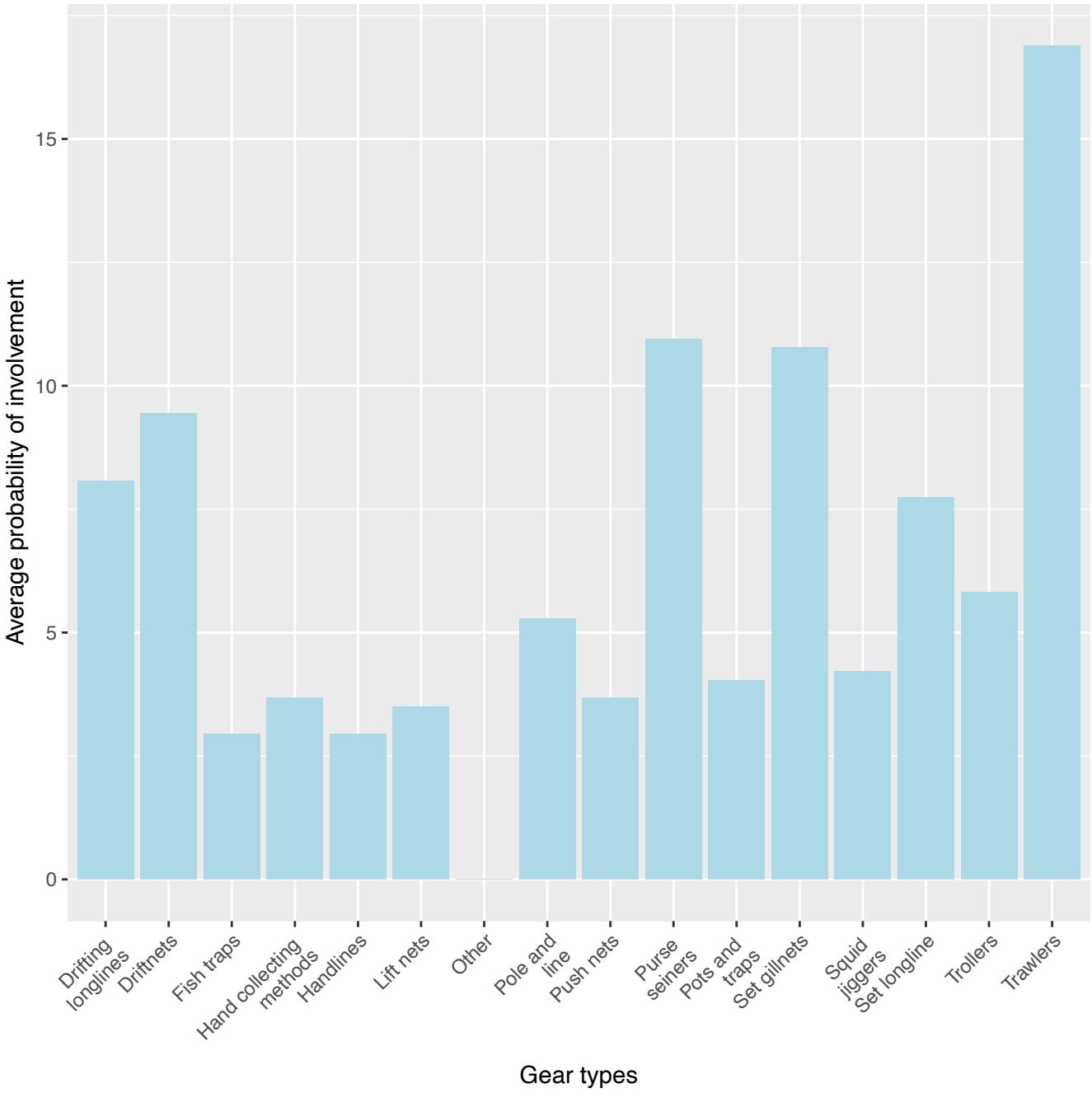

Figure 25 Perceived probability of involvement in illegal fishing by gear type (averaged over all species, based on fisheries officer survey).

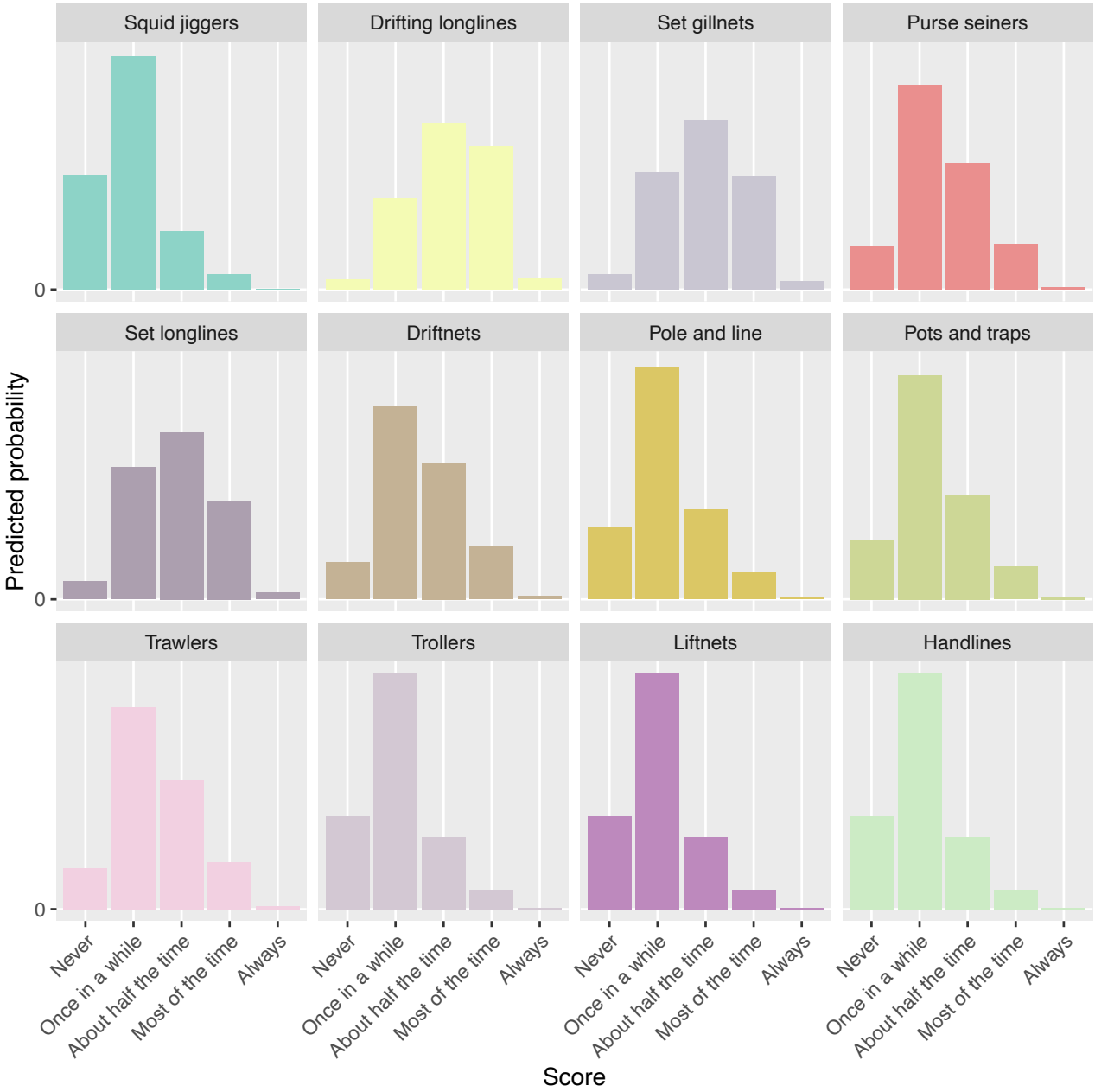

Figure 26 Perceived probability of involvement in illegal fishing by gear type (based on fisheries observer survey).

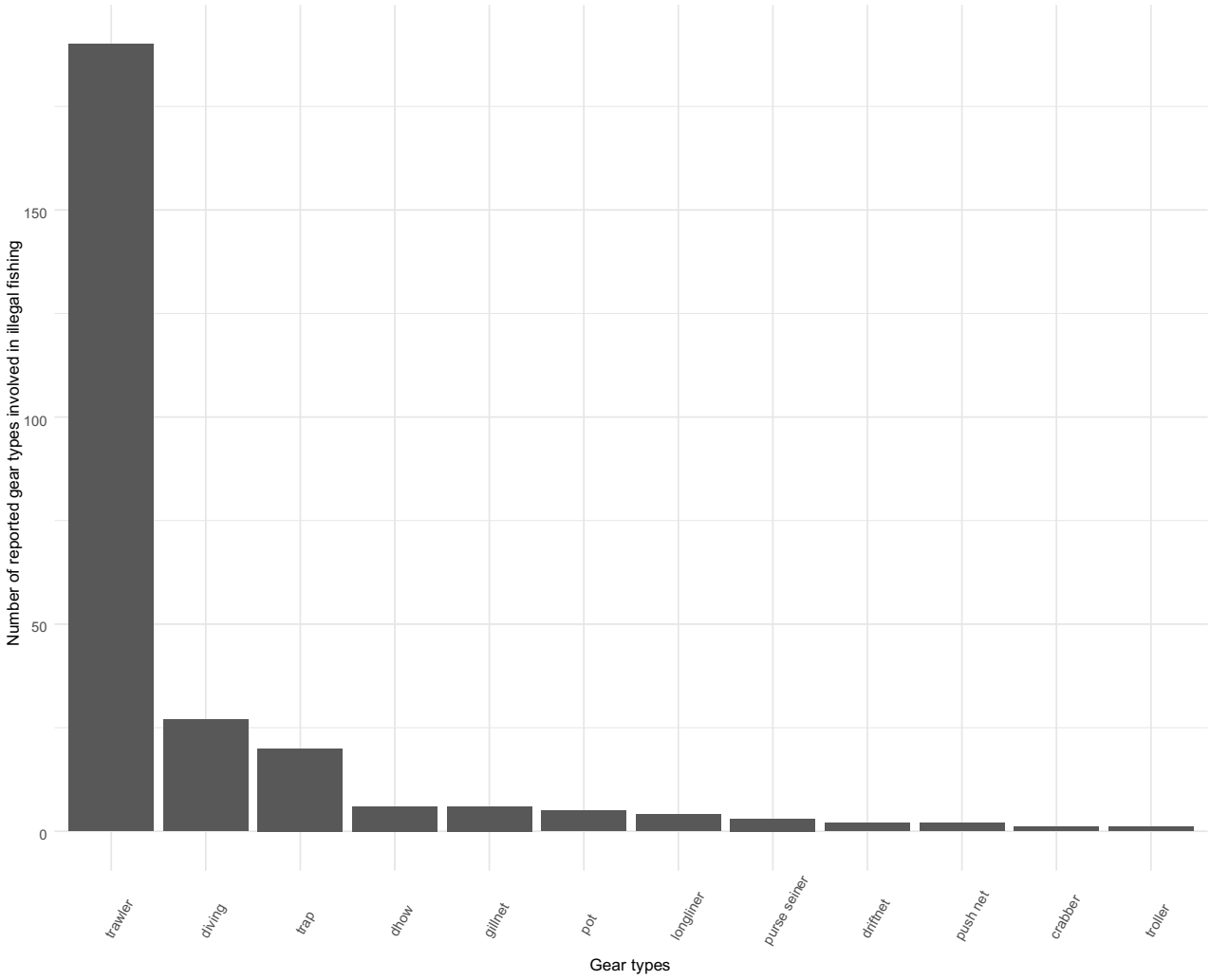

Figure 27 Gears reported to be involved in illegal fishing in the media articles (2019-2022).

4.3.8 The involvement of different vessel flags

According to the interview results, both distant water fishing (DWF) flags and regional vessels are engaged in illegal activities in the region. However, incursions and activities are not solely limited to DWF nations. It was believed that regional fleets are active within their own waters, such as illegal fishing in Kenya by Kenyan vessels, and regional domestic fleets operating in the EEZs of other coastal states. This includes Sri Lankan vessels moving south into the waters of Mauritius, Madagascar and the Seychelles. It is believed that illegal fishing is also occurring in MPAs, such as the area around the Chagos Archipelagos. Results also suggested incidents of re-flagging to circumvent regulation. For example, it was suggested that Chinese vessels have been re-flagging to Mauritian and Somalian flags to fish in certain areas.

4.3.9 Species particularly impacted by illegal fishing

In the 731 illegal fishing events contained in the extracted media, particularly general 'fish'(n=144), sea cucumber (n=25) and abalone (n=19) were reported on (Figure 28). When we link those species to the location of the illegal fishing event, we see particularly India, South Africa, Malaysia and Sri Lanka are the most commonly reported locations (Figure 28).

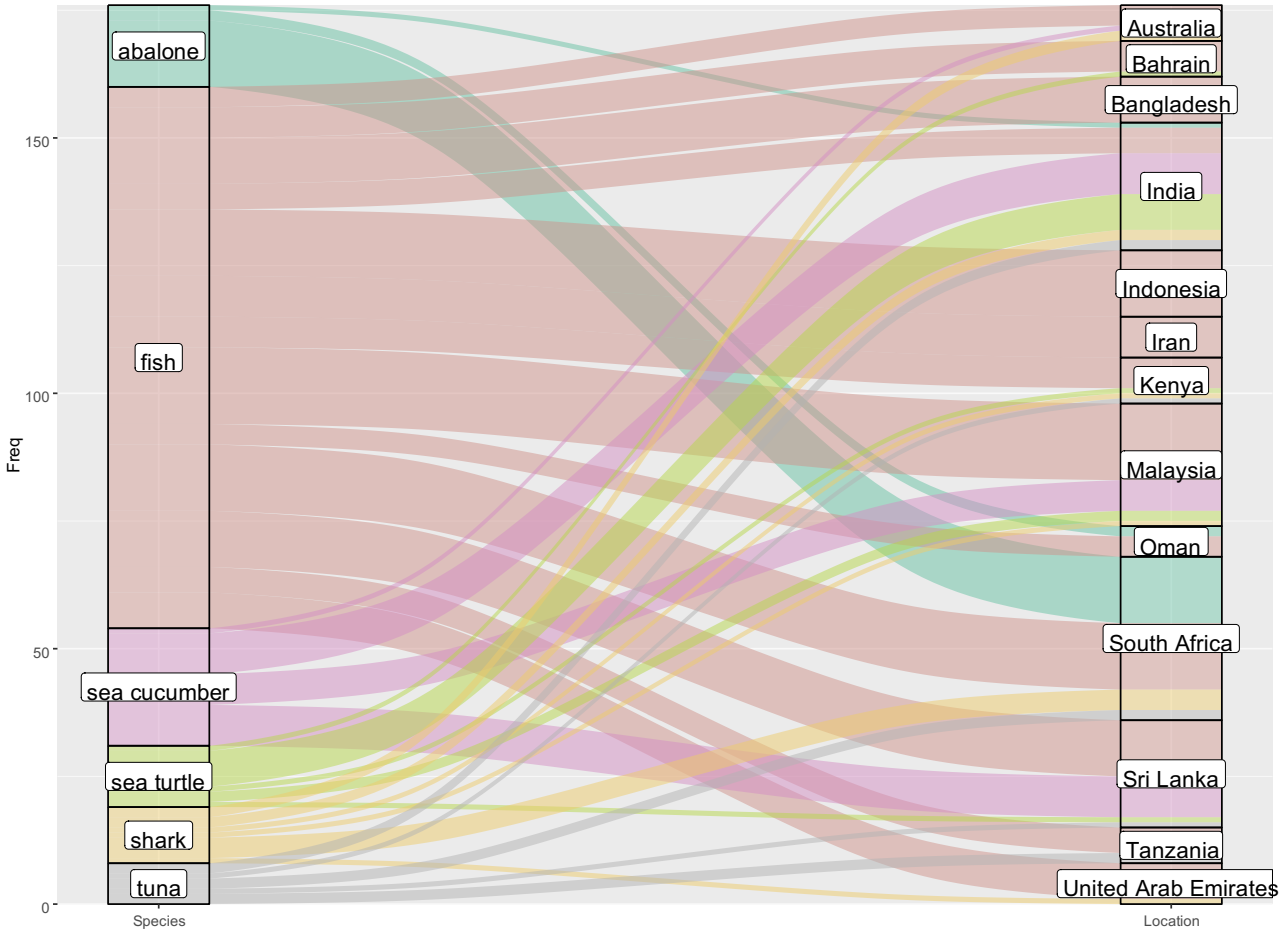

Figure 28 Most common species reported on in media data linked to the reported location of the illegal fishing event.

According to the results of the expert interviews, a wide range of species are targeted by illegal fishers from regional and DWF fleets in areas beyond national jurisdiction and inside EEZs. Tropical tuna are the key targeted species, including yellowfin, albacore, bigeye and skipjack. It was noted that while neritic tuna species are also being targeted, data has tended to focus on the illegal catch of tropical tuna species. This was raised as a concern as neritic tuna are a critical part of livelihoods for some coastal states. Other targeted species include squid, deep-water shrimp, shark (numerous

species), toothfish, prawn and swordfish. The results also identified turtles, sharks and cetaceans as species caught as incidental bycatch in illegal fishing gear.

4.3.10 Ports used to offload illegal catch

Results from the interviews suggested most illegal landings are happening at informal landing sites or port cities in the West Indian Ocean including South Africa, Kenya, Tanzania, Yemen and Oman. The interviewed experts suggested that decisions about landing locations are based on factors such as vessel type or lack of monitoring and enforcement at ports.

4.3.11 Details on unreported and unregulated fishing as opposed to illegal fishing

Fisheries observers were asked to rank how often they think illegal, unreported or unregulated fishing occurred on the high seas (as three separate categories of offenses). Unreported fishing was predicted to occur most often, and illegal fishing least often (Figure 29). For both unregulated and unreported fishing, fisheries observers indicated that particularly sharks and different species of tuna (such as yellowfin and Southern bluefin tuna) were at risk.

While it was suggested by experts that unreported fishing may have reduced from historical levels, it is still regarded as the biggest issue in the region. Examples from expert interviews of unreported fishing were limited but included concerns about the by-catch of shark species in purse seine fisheries and allegations fleets are under-reporting their tuna catch. Experts also raised problems with misreporting to avoid quota limits, pointing to an incident in 2018 which included misreporting of juvenile YFT, as well as high levels of unregulated fishing. Examples include unregulated squid fishing by Taiwanese and Chinese flagged vessels and unregulated fishing of shark species and juvenile YFT. Additionally, concerns were raised over the use of unregulated fishing gear such as bottom-set gill nets, anchored FADs in countries such as Maldives and Indonesia and the use of artificial lights in squid fishing by Chinese and Taiwanese vessels. Some experts strongly believed unreported fishing is illegal fishing as it constitutes a violation of coastal state laws or RFMO measures. However, others suggested unregulated fishing could be viewed as fraud rather than a fisheries offence.

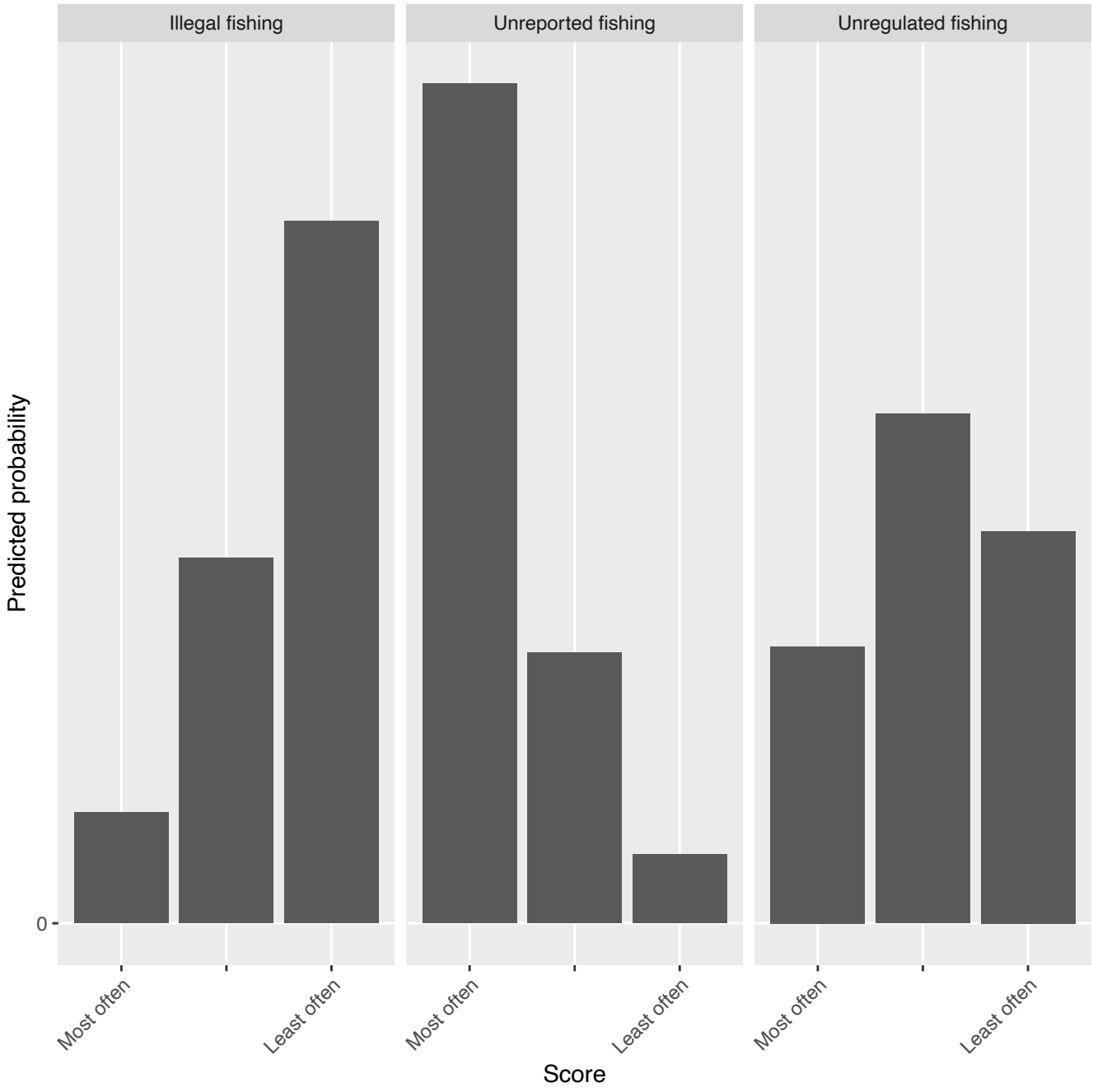

Figure 29 Perceived probability of illegal versus unregulated versus unreported occurrences on the high seas. Based on fisheries observer survey.

4.3.12 Trend of illegal fishing

For this characteristic we use the answers provided by the interviewed experts. Largely perceived to be increasing, though some experts specified further that illegal fishing is in part shifting to the north of the Indian Ocean.

Overall, results from the expert interviews suggest illegal fishing is increasing. However, it was questioned whether improvements in the quality and level of monitoring and data collection over the last decade is leading to a better understanding of the scale of the problem. While some experts perceived IUU fishing was decreasing, others suggested that there was no proof it had decreased, and it may be more likely that illegal fishing patterns are shifting due to improved control and surveillance. For example, increased regional patrols in the southern Indian Ocean means IUU fishing vessels are moving north towards the North-West Indian Ocean. A reduction in industrial fishing, but an increase from medium size semi-industrial vessels, was also identified as another changing trend.

4.4 Governance across the Indian Ocean basin

One of the primary objectives of this project is providing insight into the state of fisheries governance in the region. More specifically, this project aims to characterize policy successes and remaining challenges in the region. Here, we first present the current international institutional landscape in which we describe the organizations and actors involved in combatting illegal fishing in the different subregions of the Indian Ocean. We then discuss the results that came out of the expert interviews.

4.4.1 Overview of institutional landscape

Regional Fisheries Management Organizations in the Indian Ocean

Regional Fisheries Management Organizations (RFMOs) are one of the primary vessels for cooperation between the coastal states and fishing states on high seas fisheries management. In the Indian Ocean, the relevant RFMOs are obligated under international law to address illegal fishing activities in the Indian Ocean through management tools including minimum standards for monitoring, control and surveillance (MCS), listing IUU fishing vessels, ensuring member state compliance with Conservation and Management measures, and data-sharing and exchange of information.

There are three main RFMOs operating in the Indian Ocean: the Indian Ocean Tuna Commission (IOTC); the Commission for the Conservation of Southern Bluefin Tuna (CCSBT); and the Southern Indian Ocean Fisheries Agreement (SIOFA). In addition is the Commission for the Conservation of Marine Living Resources (CCAMLR), which is an international intergovernmental environment

organisation, with similar characteristics of an RFMO but where the objective is for conservation. The IOTC and CCSBT set conservation and management guidelines for highly migratory tuna and tuna-like species in their respective areas of competence. As a special management body, CCAMLR has a wider mandate than the management of fisheries and includes the conservation of all living marine resources in the southern Indian Ocean. SIOFA is primarily responsible for managing non-tuna fishery resources including fish, molluscs, crustaceans, and other sedentary species in the area, but excludes highly migratory species.

Table 12 Regional bodies and status of membership across the Indian Ocean. Note: Contracting Parties are members and have ratified, approved or formalised agreement. *Co-operating non-contracting Parties are not members but will cooperate with the relevant body. Acceding states are not members but are interested in engaging in fishing/research activities in the region.

Regional body	Membership
CCAMLR	*Contracting Parties:* Argentina, Australia, Belgium, Brazil, Chile, China, Ecuador, EU, France, Germany, India, Italy, Japan, Korea, Namibia, Netherlands, New Zealand, Norway, Poland, Russia, South Africa, Spain, Sweden, Ukraine, UK, USA, Uruguay and Acceding States: Bulgaria, Canada, Cook Islands, Finland, Greece, Mauritius, Pakistan, Panama, Peru and Vanuatu.
CCSBT	*Contracting Parties:* Australia, the European Union, the Fishing Entity of Taiwan, Indonesia, Japan, Republic of Korea, New Zealand and South Africa
IOTC	*Contracting Parties:* Australia, Bangladesh, China, Comoros, Eritrea, European Union (Member Organization), France, India, Indonesia, Iran (Islamic Republic of), Japan, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Oman, Pakistan, Philippines, Republic of Korea, Seychelles, Sierra Leone, Somalia, South Africa, Sri Lanka, Sudan, Thailand, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, Yemen *non-Contracting Parties:* Liberia, Senegal
SIOFA	*Contracting Parties:* Australia, China, the Cook Islands, the European Union, France on behalf of its Indian Ocean Territories, Japan, the Republic of Korea, Mauritius, the Seychelles, Thailand *Participating fishing entity:* Chinese Taipei *non-Contracting Parties:* Comoros, India *Signatories to Agreement:* Kenya, Madagascar, Mozambique, New Zealand

Pan-regional organizations: IORA, SIOTI

Established in 1997, the Indian Ocean Rim Association (IORA) has one of the largest memberships of the region with over 23 member countries and over 10 dialogue partners (see Table 13 for membership). As a pan-regional organisation, IORA's primary focus is the facilitation and promotion of economic cooperation across the entire Indian Ocean region. IORA has identified IUU fishing as a major threat to security and economic development and supports member states to improve technical infrastructure to combat illegal fishing through training and programs. IORA does not currently have any formal partnerships with other fisheries management bodies in the Indian Ocean but is seeking partnership with the Indian Ocean Tuna Commission. The IORA Fisheries Support Unit (FSU), based in Oman, acts as the body's regional centre for research facilitation and capacity building.

The Sustainable Indian Ocean Tuna Initiative (SIOTI) was formed in 2017 as a collaborative Fisheries Improvement Project (FIP) between major tuna processors and tuna producer organisations and their fishing vessels in the region, with support from the World Wildlife Fund (WWF). SIOTI's key aim is to improve the fishing methods of purse-seine tuna fisheries in the Indian Ocean (Area 51 and 57) so it meets the highest standard of sustainable fishing. SIOTI invites stakeholders across the supply chain to be engaged with the FIP through MoUs. For example, the Seychelles Fishing Authority works with SIOTI vessels in the region to reduce the number and impact of Fish Aggregating Devices (FADs). SIOTI has requested an extension on its progress report which is due in June 2023. However, its current FIP rating is high (Advanced Progress).

Organizations in East Indian Ocean: BOBP-EGO, QUAD, AN-IUU, RPOA-IUU

In East Indian Ocean, IUU fishing is the focus of several regional bodies and initiatives, aside from the RFMOs. The Bay of Bengal Programme (BOBP-IGO) is a Regional Fisheries Advisory Body (RFAB) for the countries that border the Bay of Bengal region (see Table 13 for membership). It works closely with regional groups and other stakeholders to address barriers to sustainable fisheries management.

Formed in 2022, the Quadrilateral Security Alliance (QUAD) (see Table 13 for membership) announced that combatting IUU fishing in the Indo-Pacific will be a priority for the diplomatic partnership. According to QUAD leaders, new surveillance technology is being developed to track illegal fishing by Chinese vessels in the Indian and Pacific Oceans. The network is a key pillar in

Australia's foreign policy and Australia will be hosting the 2023 QUAD summit. While no formal partnerships have been announced, the QUAD have stated it will work directly with other inter-governmental organisations in the region, including the Association of Southeast Asian Nations (ASEAN).

The ASEAN Network for combatting IUU fishing (AN-IUU) (see Table 13 for membership) was established in 2019 as a regional monitoring, inspection and information exchange platform. AN-IUU followed several other attempts by ASEAN countries to improve fisheries policy framework after concerns that IUU fishing was evolving into a maritime security threat in the region. ASEAN member states also work bi-laterally with other countries to address IUU fishing. For example, Japan has funded capacity-building programs and provided monitoring vessels to Indonesia to deter illegal fishing.

Established in 2007 by Australia and Indonesia, the Regional Plan of Action against IUU Fishing (RPOA-IUU) is a ministerial-led initiative focused on deterring IUU fishing in the Southeast Asian region and promoting sustainable fishing practices (see Table 13 for membership). Participating countries meet annually to share information, report on MCS progress and share data on IUU fishing vessels. RPOA-IUU is widely recognised as a best-practice model for regional cooperation. However, capacity gaps between member states remains an issue.

Organizations in West Indian Ocean: Stop Illegal Fishing, FISH-i Africa, SADC, IOC, SWIOFC, IGAD, RECOFI

Through regional cooperation, African coastal states have made considerable progress towards combating IUU fishing in the West Indian Ocean. Formally established in 2013 as an independent NGO, Stop Illegal Fishing has become a key partnership in both government and non-government initiatives and advise on the African Voice at the United Nations Committee on Fisheries. Its success led to the establishment of the East African FISH-i Africa (see Table 13 for membership) partnership which regularly brings together member states and national enforcement authorities, regional organisations, and global experts to improve management, surveillance, and enforcement capacity.

The South African Development Community (SADC) is a Regional Economic Community comprising 16 member states (see Table 13 for membership). SADC address IUU fishing through the development of regional and sub-regional collaborative mechanisms. In March 2023 SADC's Fisheries MCS Coordination Centre (MCSCC) entered in force. MCSCC coordinate MCS measures

across member states including border controls, vessel inspection and intelligence sharing. This was an important milestone for SADC who had been working closely with other regional projects including FISH-i Africa, which was integrated into the MSCSS in 2020.

The Indian Ocean Commission (IOC) is comprised of five South-East African island member states (see Table 13 for membership). The IOC coordinates several IUU fishing initiatives with other regional programs. IOC is currently working with Stop Illegal Fishing on the VISIBLE project, an open database of information on fishing vessels, focusing on those operating in the African region. In collaboration with the European Union and other African regional bodies, IOC also oversee the implementation of E€OFISH program activities. One major achievement funded by the European Union through the E€OFISH Programme is the Regional Fisheries Surveillance Plan (PRSP). The PRSP, which has seven participating countries namely Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles and Tanzania, combats IUU fishing through several avenues, such as resource pooling (e.g., surveillance officers, patrol vessels and airplanes) for regional joint deployment plans and data exchange (e.g., sharing of VMS data) (Swan, 2022). The Intergovernmental Authority on Development (IGAD) is an eight-country regional economic bloc in Africa established in 1996 (see Table 13 for membership). The IGAD Security Sector Programme (IGAD SSP) set up a Maritime Security Pillar in 2013, based in Addis-Ababa. IGAD has been instrumental in the development of a regional strategy for the management of IUU fishing and has implemented several initiatives to combat illegal fishing in the region.

Since 2004, the South West Indian Ocean Fisheries Commission (SWIOFC) has been working to promote the sustainable utilisation of all living marine resources in the southwest Indian Ocean (see Table 13 for membership). It is a well-established advisory group with support from a wide range of stakeholders including the IOC, IOTC and FAO who contribute to annual SWIOFC sessions. SWIOFC was the first FAO Article IV body to undertake an external performance review and has made considerable progress on several important instruments. This includes guidelines on Minimum Terms and Conditions (MTC) for Access of Foreign Fisheries to the SWIOFC region, which was adopted by all member states in 2019. SWIOFC is instrumental in developing minimum terms and conditions for granting foreign fishing access.

Finally, the Regional Commission for Fisheries (RECOFI) is a regional fisheries body that promotes the development, conservation, and rational use of living marine resources in national waters off

East and North Africa. RECOFI is the only regional body made up entirely of Arab states (see Table 13 for membership).

Global organizations: FAO, INTERPOL, IMCS Network

There are also a number of important global organisations and NGOs working in the region. This includes INTERPOL which views fisheries-associated crimes as a significant threat to global and national security and works with member countries to identify and apprehend IUU fishing vessels through Interpol Purple Notices, detect and dismantle criminal networks in the fisheries sector and build national investigation and prosecution capacity. Working globally but often with a regional focus, NGOs such as IMCS Network and WWF, are focused on identifying and closing gaps in regional cooperation, MCS and enforcement. Finally, as the largest global inter-governmental organisation the FAO plays a significant role in Indian Ocean fisheries governance by leading and coordinating regional initiatives. FAO also provide guidance to RFMOs.

Table 13 Governance and membership across the Indian Ocean

Institution/Body	Membership
AN-IUU	Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam
BOBP-IGO	*Current members*: Bangladesh, India, Maldives and Sri Lanka. *Cooperating non-contracting parties*: Indonesia, Malaysia, Myanmar and Thailand
FISH-i Africa	Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Tanzania, and Somalia
IGAD	Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Uganda
IOC	Comoros, France in respect of Reunion, Madagascar, Mauritius and the Seychelles
IORA	Australia, Bangladesh, Comoros, France, India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Oman, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania, Thailand, the United Arab Emirates and Yemen. *Dialogue partners*: China, Egypt, Germany, Italy, Japan, Russia, Turkey, the Republic of Korea, the United Kingdom and the United States of America
QUAD	Australia, the United States, Japan and India

RECOFI	Bahrain, Iraq, Iran (Islamic Rep. of), Kuwait, Oman, Qatar, Saudi Arabia, United, Arab Emirates
RPOA-IUU	Australia, Brunei Darussalam, Cambodia, Timor-Leste, Indonesia, Malaysia, Papua New Guinea, the Philippines, Singapore, Thailand and Vietnam
SADC	Angola, Botswana, Comoros, DRC, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, United Republic of Tanzania, Zambia and Zimbabwe
SWIOFC	Madagascar, Somalia, South Africa, Mozambique, Egypt, Seychelles, Comoros, France, Kenya, Maldives, Mauritius, Tanzania and Yemen

4.4.2 Expert interview results

Here we present the key outcomes of semi-structured interviews conducted with experts as they pertain to the governance context of the Indian Ocean (see 14 for the interview guide). As described in the method section, we have 6 specific questions that relate to governance from the expert interviews, each are outlined here.

Primary drivers of illegal fishing

Corporate greed, poverty and lack of awareness were clearly identified by the experts as the key barriers to tackling illegal fishing. Results suggest that illegal fishing perpetrated by owners, operators and companies involved with industrial and DWF fishing are perceived to be motivated by greed and profit, while illegal fishing perpetrated by small-scale fishers or vessel crew are perceived to be motivated by poverty, food security and lack of alternatives options. Links between domestic political situations and the ability of a country to effectively manage illegal fishing was also noted, including the pressures of overpopulation.

Successful recent policies and innovations

Many experts indicated that regional countries were actively bolstering their regional cooperation and improving national policies and practices to constrain illegal fishing. This included the adoption of crew-based observer programs and by-catch mitigation projects in countries such as Sri Lanka and Pakistan and co-management plans in the Seychelles. Other examples included increased investment in joint-operation centres, aerial patrols and strengthening monitoring capacity through

regional partnerships in countries such as Kenya. Results highlighted the positive outcomes of collaboration between countries and regional and global organisations in the region, such as SADC, Fish-i Africa, E€OFISH, TMT and GFW, and the contribution of these groups in improving access to technology and intelligence. Additionally, some countries indicated their plans to tackle illegal fishing by reviewing and strengthening national EEZ conservation legislation and in the case of South Africa, re-establishing the 'green court', the specialist environmental court that dealt specifically with marine poaching. Others suggested that fighting corruption in illegal fishing required new policy ideas such as coastal states introducing character checks before granting fishery licences.

Primary barriers to tackling illegal fishing

While not necessarily linked to illegal fishing, the expert interviews also revealed broader issues relating to high seas fisheries management in the region. This includes a perceived lack of transparency and reliability around allocation mechanisms and data validity in tuna RFMOs. For example, it was implied that some IOTC Members may be inaccurately revising their catch limits of certain tuna and tuna-like species, such as yellowfin, to increase allocation thresholds. Other experts allege Members often submit false or misleading data and information to the IOTC. However, it was noted by interviewees that it is difficult to determine the accuracy of these claims as data is limited and insufficiently tracked by certain coastal states. Additionally, there are significant delays between data reporting and RFMO decision-making processes. For example, some out-of-the-ordinary catch data patterns for tuna and tuna-like species submitted to the IOTC several years ago is still under scientific analysis. These issues make it increasingly challenging for RFMOs to perform effectively. It was also noted that Member States have been pushing back against the Secretariat's request they provide compliance data from regional and national observer schemes.

Related crimes

Most experts expressed that they believed illegal fishing is often connected to criminal activity and organised crime networks. Drug smuggling was identified as the crime most intricately linked with illegal fishing. The discovery of 143kg of heroine on a semi-industrial fishing vessel was used as a recent example. Experts suspected other criminal behaviour such as trafficking of humans, weapons and wildlife also closely overlap with fishing crimes and believed they knew of several routes that smugglers would take, including from South Asia into East Africa.

Impacts of illegal fishing

Overall, experts viewed the impact of illegal fishing as significant. This included the perceived impact on the environment, such as biomass decline and stock collapse, habitat destruction because of illegal fishing gear, appearance of invasive species and threats to the broader ecosystem. However, it was noted that it is difficult to estimate the extent of the impact on the environment as data on species and stock decline is often limited. The socio-economic impact of illegal fishing on coastal states included loss of jobs and lack of employment opportunities due to the closure of fishing factories, decline in specific fish stocks (such as prawn) impacting community food security and loss of local revenue due to illicit financial flows.

5 Discussion

5.1 Volume and value of illegal fishing: discussion

This report provides a regional estimate of illegal fishing in the Indian Ocean. Previous regional estimates for the western Indian Ocean over the period 2000-2003 were estimated to be in the order of 18% (as the mid-point between lower and upper estimates of both illegal and unreported catch for the case study species, expressed as a percentage of reported catch of the case study species), and 32% in the East Indian Ocean (Agnew et al., 2008). In contrast here, as the first specific regional estimates, 27% of total landed volume was estimated to be illegal, equating to roughly 1.3 million tonnes, and USD$1.3bn. In contrast, the global estimate in 2003 (Agnew et al., 2009) of 18%, equated to a global value of USD$5-11bn, and the upper value estimate for the eastern and western Indian Ocean combined was roughly 1.38 billion. However, it is important to note that these estimates hinge not only on the accuracy of our methodology, but also on the validity of the catch data reported to FAO. Some experts maintained that, for some countries, reported catch data might be (grossly) overstated. If this is true, our results are an overestimation.

From the media analysis, much of the illegal activity focused on fish species, with a high proportion of activity (by value) undertaken by the domestic fleet (rather than foreign vessels). This suggests that for most countries, illegal fishing is undertaken mostly by domestic vessels/individuals operating illegally in their own waters. This contrasts with the study by Wilcox et al. (2021) which found that most illegal fishing (by value) was undertaken by foreign fleets in the Asia Pacific region. There were many incidents by shore-based fishers involving small quantities of high value species (e.g., abalone, sea cucumber). In terms of overall value, however, these incidents were minor. As noted previously, the analysis was based on reported incidents. This is a function of the level of monitoring and surveillance which leads to their detection. This varies by country and may influence both the type of infringement observed in the data as well as the quantities.

Undiscovered incidents of illegal fishing may be substantial. Moreover, the number of incidents reported in English speaking media might be low for some countries in the region. The level of information included in the media reports was highly varied. Where some quantitative data were available, these mostly involved some measure of the number of vessels and/or number of individuals involved. Some included the estimated total value of the catch, with others providing an

estimate of the total quantity (and some both). In terms of the species associated with the activity, most identified these generically (e.g., fish, squid, tuna, crabs). Where species were identified more specifically (e.g., blue swimmer crab), these tended to be smaller incidents in terms of the volume/value of catch. Incidents of catch of threatened or endangered species only included quantitative information when the species were retained by the fishers to be sold commercially (e.g., whale shark, turtles). Many of the reports excluded from the analysis claimed that illegal fishing was responsible for stock collapses, loss, or damage to coral cover, or, in many cases, responsible for the deaths of protected species found on the shore (e.g., turtles, dugongs, dolphins). While this may be the case, the perpetrators of these activities were not identified in the media reports and could not be included in the analysis.

A key challenge in the region is the accuracy and validity of reported catch data. This concern was also raised in a recent report by Zeller et al. (2023) who highlighted significant knowledge gaps in the Indian Ocean due to a high uncertainty around official catch data. The potential for overstated catch data results in inflated estimates of illegal fishing, and challenges in accurate stock assessments, and any subsequent decision making. In contrast, for several reasons, small-scale fisheries catch has been chronically underrepresented in official catch data and may be far more important for food security than previously realised. Despite representing 40% of total catches in the Indian Ocean, a number significantly higher than the global average of 25%, 20% of artisanal and 80% of subsistence fishing remain unreported (Zeller et al., 2023). Furthermore, the small-scale sector is often not differentiated within official international statistics of IUU fishing (Zeller et al., 2023). This raises concerns about the political marginalisation, and potential criminalisation, of small-scale fisheries in national and international IUU laws and regulations (Song et al., 2020).

It is important to keep in mind that the value of illegal fishing calculated here (or anywhere for that matter) i.e., 1.3 billion USD, is not completely lost to the economies of countries around the Indian Ocean. The actual economic impacts of the value of illegal fish taken out of the Indian Ocean is difficult to estimate. For the catch taken away from the region (which, for example, it is likely that a large component of yellowfin tuna would be), that would represent significant economic impacts on and loss to the coastal states of the Indian Ocean. Though the model that included region was not the most predictive model of illegal landing scores (meaning that the extent of illegal landings across species did not vary significantly regionally), there are some species for which illegal fishing seems to be a more localized issue.

Yellowfin tuna, which represents a significant loss in terms of volume and value, is of importance for export to the EU, US or Asian markets. Though one could argue this fishery has only a limited contribution to food security in West Africa, a significant amount of the stock is targeted by artisanal fisheries as well. The tuna and tuna-like species are estimated to account for at least 15% of the total global small-scale fisheries catch (FAO, 2022). In comparison, shrimps and prawns do contribute to regional livelihood and food security (WWF, 2023). In the West Indian Ocean (particularly the southern part), Penaeidae shrimp stocks are an important source of export revenue, however, the FAO notes that the stocks show obvious signs of overfishing (FAO, 2022).

This localisation and distinction of impact to the region is also reflected by the destination markets for specific species, which from the initial list of 30, tended to be primarily local markets. It must be considered that this is the destination market for specific species in our list, which does not include species such as certain high-value tunas such as bigeye or albacore tuna, the majority of which is known to end up in European, Asian, and American markets (Stop Illegal Fishing, 2020).

There are increasing concerns about the over-exploitation of some high-value target species, such as squid, with neither RFMO regional mandate nor international body in place to regulate the fishery. One study estimates unregulated squid fishing has expanded 830% from 2015 to 2020 (WWF and TMT, 2020). In 2015 it was estimated only around 13 vessels were involved in squid fishing in the northwest Indian Ocean, in comparison, recent estimates indicated upwards of 280 vessels targeting an unregulated fishery. While unregulated fishing is not the focus of this study, it is important to note both the species and spatial gaps in regional frameworks as opportunities for reform. Like squid, there are also emerging concerns about a lack of regional regulation and poor national monitoring for shrimp and prawn catches in the West Indian Ocean, despite the importance of the fisheries as a source of foreign income and security for the region. A recent report by WWF estimated that a quarter of all shrimp fishing activities were potentially illegal and unregulated between 2016 and 2021 with potential economic losses for coastal states in the region amounting to around 47 million USD each year (WWF, 2023).

Consideration on and next steps for unregulated fishing, particularly squid, in the region is of high importance. If and how this is regulated is a key challenge for the region.

5.2 Hotspots of illegal fishing: discussion

The media results indicate different hotspots of illegal fishing than the survey for fisheries officers. Primarily, this is due to the biased nature of media data: these results reflect the availability of English-speaking media to a large extent. Nonetheless, India is likely to be a hotspot picked up by the media results which are not reflected in the survey results (as we did not manage to get responses from Indian fisheries officers).

Two other key global efforts in recent years are the Global Fishing Index (GFI) (Minderoo Foundation, 2021) and the IUU Fishing Index (Macfadyen et al., 2019). Both provide insights into global governance and risk associated with illegal fishing and overfishing, and support findings from this regional study. There are several areas in high agreement between the GFI for areas scoring poorly for overfishing, and hotspots noted here for illegal fishing. It is worth noting that there is an overlap between illegal fishing and overfishing, the former being a driver of the latter. Both the GFI and our study highlight the horn of Africa (waters around Somalia) as well as areas around Pakistan and the Bay of Bengal region, and to some extent the area around Madagascar and Mozambique.

The East Indian Ocean was identified as the worst-performing region and ocean basin overall in the 2019 IUU Fishing Index. However, the 2021 Index identified the West Indian Ocean as an area of increasing high risk and the West Indian Ocean replaced the Western Pacific as the ocean basin with the worst score. Countries that gained prominence in terms of poor scores in the 2021 Index included Somalia and Seychelles, the latter entering the worst-performing list for the first time based in part on the country registering vessels with foreign and unknown ownership. In the 2021 Index, the Middle East was specifically flagged as a region of concern. While the GFI did not have data on Yemen, both the 2019 and 2021 Index highlighted Yemen's mediocre performance in terms of actions that reduce the risk of illegal fishing. GFW has also identified Yemen, and the waters off Somalia, as an area of substantial risk (TMT & GFW, 2020).

5.3 Characteristics of illegal fishing: discussion

From the survey, media and interviews we gain deep insights into the characteristics of illegal fishing across the region.

5.3.1 Violations vary across industries and gears

From survey for fisheries officers and expert interviews, use of illegal gear is more often an issue for small vessels such as the pervasive use of monofilament gears. Also fishing for juvenile/undersized species is an issue with small vessels. For large vessels, fishing for undersized or protected species, fishing with unauthorized gear or fishing without a valid license were most perceived to occur 'often' by fisheries officers. The prevalence of fishing without a license was flagged in a previous report regarding the West Indian Ocean, although fishing with unauthorized gear was previously found to be an uncommon violation (Bergh, 2022). However, besides this report, there is no comprehensive estimation on the use of unauthorised fishing gear in the Indian Ocean.

In the survey for fisheries officers, trawlers were perceived to be most involved in illegal fishing, followed by purse seines and set gillnets. In the survey for fisheries observers, particularly drifting longlines, set gillnets and set longlines were perceived to be involved in illegal fishing more often than the other gear types. Longlines are, after purse seines, the most common tuna-fishing method and about 500 of them operate in the West Indian Ocean, mostly flagged to countries such as Taiwan, Spain, Indonesia, China, Portugal and Japan (Stop Illegal Fishing, 2020). Longlines are particularly common gears for catching albacore and bigeye tuna (Stop Illegal Fishing, 2020) (these species were not part of our survey, so we do not have estimates for their illegal landings). Though more yellowfin tuna is caught by purse seines, longlines also target yellowfin tuna, which, according to our survey results, is often landed illegally.

Set gillnets, as well as drifting gill nets, two gears thought to be involved in illegal fishing, have been flagged as most likely to be causing significant bycatch of cetaceans (International Whaling Commission, 2019). For the Indian Ocean, estimates of non-target marine catch in tuna gillnet fisheries (drift nets in particular) have been estimated annually at 100,000 cetaceans, 97,000 tons of elasmobranchs and 29,500 sea turtles (Roberson et al. 2022). Throughout the region there is continued use of illegal gear, and gear associated with high-risk activities.

In 2020 TMT and GFW, in collaboration with the Somali Government, identified at least 175 Iranian vessels fishing without a license in Somalian and Yemeni EEZs. The report suggested the fishing gear used by these fleets was pelagic gillnets (TMT & GFW, 2020). The use of illegal gillnets and other unauthorised fishing gear by Chinese, Indian and Pakistani vessels have also been identified as problematic. For example, in 2019 ten Chinese fishing vessels were found to be carrying banned gear, including drifting gillnets and bottom trawl nets (Bhatt, 2020).

The impact of illegal fishing gear and fishing for juvenile and protected species has a significant impact on the region. Abandoned, lost or discarded (ALD) fishing gear is a major threat to marine habitats and biodiversity and is closely linked with illegal fishing. The use of gillnets and FADs are identified as posing the highest risk of damage, with gillnets being the primary source of 'ghost fishing' (Thomas et al., 2019). The extent of the problem in the Indian Ocean is unknown due to limited ownership and reporting of gear and lack of standardised regulation and data collection. However, countries such as the Maldives are particularly vulnerable to floating marine debris due to their location. It is reported that between 2013 and 2017 over 700 conglomerates of nets and other fishing gear was recovered by volunteers (University of Bristol, 2023). Fishing for juvenile and protected species in the region is also having a detrimental impact on the environment. This is highlighted as a serious concern in the location of the Great Chagos Bank where it was reported that sharks were caught by Sri Lankan and Indian vessels suspected of illegal fishing between 2010 and 2020. This included critically endangered species and juveniles (Collins et al., 2021). According to a 2020 Stop Illegal Fishing report, sharks are still targeted by longline vessels who retain fins in contravention of the 5% fin to carcass ratio set by the IOTC. While marine discards are lower in the Indian Ocean compared to other ocean basins (Zeller et al., 2018), several studies have highlighted the impact of tuna fisheries by-catch on species decline in the region, including silky sharks and albatross (CITES, 2017; Petrossian et al., 2022).

5.3.2 Sectors involved in illegal fishing

The Indian Ocean is dominated by domestic small-scale vessels and fishing activities (Zeller et al., 2023), with estimates in 2006 indicating that regionally, the small-scale fisheries sector employed at least two and a half times more than the industrial sector. Consequently, the impact of illegal fishing, and nature of the activity and species impacted varies across the region. Species such as the Indian oil sardine, shrimps and prawns or coral reef fish are thought to be fished illegally predominantly by small vessels (<12 meters), whereas marine turtles and the tunas are more likely

to be impacted and fished illegally by larger vessels. Of key interest and importance in the Indian Ocean region is the involvement of industrial/semi-industrial, and even artisanal vessels, that fish beyond national waters. For example, vessels from Sri Lanka have been found illegally fishing in the Seychelles, India and British Indian Ocean Territory (Collins et al., 2021).

Management and monitoring of these small-medium sized domestic industrial vessels is a challenge for the region. A 2022 report on the expansion of industrial fishing in Madagascar's EEZ found DWF fleets dominated Madagascar's overall fishing activities. The study (White et al., 2022) revealed that 17.6% of fishing vessels were operating near off-limit areas including within MPAs. Regionally, the use of monofilament nets results in an array of impacts, from capture of fingerlings, complete lack of specificity and high species capture (Dzoga et al., 2020), through to ending up as ghost nets and the devastation and impacts associated (Stelfox et al., 2014). Blast-fishing also continues to be a challenge for parts of the region. Historically, poverty was considered to be the dominant driver, however recent research has indicated that convenience and increased catch is key, with blast fishing occurring in areas of both low and high socioeconomic development (Hampton-Smith et al., 2021). Understanding regional and local context, drivers, and capacity are fundamental. Effective enforcement, at a national centralised agency, or through locally managed efforts (or a combination of the two), is also vital to the reduction of blast-fishing (Haisfield et al., 2010).

5.3.3 Drivers of illegal fishing

Though some overlap in drivers of illegal fishing exists across the region, our results indicate that there are distinct incentives dependent on the profile of the fishery (such as vessel size and profitability of the fishery). Regionally, poverty and lack of alternative livelihoods is a strong driver for local populations (artisanal and subsistence fishers), while economics, on its own driven by increased domestic and international demand for fish, is more commonly associated with large scale industrial vessels. Understanding the underlying causes and drivers of illegal fishing is key to affecting long lasting change. Whilst profit beyond fulfilling basic needs is a motive for illegal fishing in some cases, regional depletion of fish stocks causing displacement, diminished income and lack of alternative livelihoods are all well-established reasons for illegal activity. Importantly, in such a varied region, understanding the different drivers across social and cultural contexts is fundamental. Particularly in small scale coastal fisheries, lack of knowledge is in some cases driving violations. In other cases, low fines may not discourage illegal fishing, implying both intention and knowledge. A

study of illegal fishing activities in the Table Mountain National Park MPA off the Western Cape, South Africa, found that illegal harvesting of marine resources had increased significantly between 2000 and 2009 with concerns the trend may be much higher due to under-reporting. The study suggested that fisheries non-compliance was a result of multiple factors including poverty, poor stakeholder consultation in the formation and management of the MPA and weak enforcement and prosecution measures (Brill & Raemaekers, 2013). Regionally, subsidies also continue to prop up illegal fishing, particularly of distant water fishing (DWF) fleets (Arthur & Hayworth, 2019), leaving local fleets at a disadvantage, unless they too are subsidised (Okemwa, 2023). In their 2013 analysis of small-scale fisheries in Mozambique the South African Institute of International Affairs (SAIIA) (Chevallier, 2013) argued that the rise of piracy on the coast of Somalia has been linked to illegal fishing by foreign trawlers. The study suggests that the expansion of industrial fishing has put significant pressure on fish stocks, leading to conflict between small-scale fishery communities and industrial vessels.

5.3.4 Key actors and infrastructure

There is a wide range of actors involved in Indian Ocean fisheries, as well as steps in supply chains, from local fishers to regional groups, to transnational syndicates, from informal landing sites and local markets, through to free ports and internationally bound transhipment. Regionally, of key importance is the role of 'middlemen' or agents. Structurally, in small scale domestic fisheries, these intermediaries are in direct contact with fishers at landing sites, whilst in larger fisheries they may be the agent for a larger collective. They are a key actor and contact point in the infrastructure supply chain and have substantial influence in their role in small scale fisheries. In many cases, the intermediary is not only the key route to market, but also the line of credit and capital, resulting in labour-tying loans and ongoing control (Crona et al., 2010; Miller et al., 2019). The role of agents in facilitating and continuing illegal activity is key across all aspects, and specifically of concern in the region is the role of non-National agents, who are key point of contact for handling vessels of DWF flags. These agents often act as the key communication route between government, industry and, particularly for foreign vessels (Crona et al., 2010).

Processors in the region are also a potential route for illegal activity, with the purchase of illegally sourced catch potentially legitimized during processing with that from fully licensed vessels. The Seychelles experienced such an issue in the sea cucumber fishery, with the lack of timely catch and effort data by fishers, and processing data by the processors. This lack of data proved challenging to

assess and reconcile the sea cucumber sold by fishers, and the amount of bêche-de-mer produced by the processors. Without accurate information, it was challenging to determine the extent of laundering of illegally caught sea cucumbers. As a solution, they introduced a sales receipt book into the supply chain, that was required to be counter-signed by both the seller and the buy. Though a positive step in acknowledging and tackling such a challenge, this implementation has still proved difficult, with reluctance from both fishers and processors (Aumeeruddy & Conand, 2008).

Ports are a key infrastructure to monitor for illegal fishing interception. For the tuna fisheries, there are four main ports in the region: Port Victoria (Seychelles), Port Louis (Mauritius), Antsiranana (Madagascar) and Cape Town (South Africa) (Stop Illegal Fishing 2020).

5.3.5 Links to other crimes

Globally, there has been considerable focus on the links between vessels fishing illegally, and other criminal behaviour (Coning & Witbooi, 2015; Bueger, 2015; Chapsos & Hamilton, 2019; Mazaris & Germond, 2018). Although not all illegal fishing is linked to organised crime, there is compelling evidence that this trend is no exception in the region. Illegal fishing is rarely an isolated or opportunistic offence and is far more likely to be linked with a range of enabling crimes systematically undertaken to increase profit (Stop Illegal Fishing, 2017). Links to other crimes in the region include arms smuggling, drugs smuggling, the use of slave labour and indentured servitude, wildlife trafficking and money laundering and fraud (Mazurek & Burroughs., 2018; UNODC 2013). There is also evidence that local vessels, traditionally used for fishing, are being used to transport drugs. For example, the transporting of drugs using dhows from the southern Iran and Pakistani coastline to East Africa, with Tanzania a frequent import entry route (Permission to Board, 2023). In 2016 an Iranian fishing dhow was apprehended in Seychelles waters and was found to be carrying almost 100 kilograms of heroin and almost one kilogram of opium (GI-TOC, 2021). In contrast to trafficking of drugs, in South Africa fishers have been coerced into providing fuel to transnational organized crime groups, and in return have been paid in crystal methamphetamine (Shaver & Yozell, 2018).

5.4 Governance for fighting illegal fishing: discussion

Illegal fishing in the Indian Ocean is the focus of a wide group of multilateral inter-governmental organisations, non-governmental organisations (NGOs) and the private sector. This includes (but is not limited to) four regional bodies (three RFMOs, and CCAMLR), the Indian Ocean Rim Association (IORA), the Southern African Development Community (SADC), Stop Illegal Fishing, Fish-i Africa (established by Stop Illegal Fishing), The Intergovernmental Authority on Development (IGAD), E€OFISH, the Southwest Indian Ocean Fisheries Commission (SWIOFC), the Bay of Bengal Programme Inter-Governmental Organisation (BOBP-IGO), the ASEAN Network for Combatting IUU Fishing (AN-IUU), the Regional Plan of Action for Combatting IUU Fishing (RPOA-IUU), the Regional Commission for Fisheries (RECOFI), the Indian Ocean Commission (IOC), Sustainable Indian Ocean Tuna Initiative (SIOTI), the Quadrilateral Security Alliance (QUAD), the Food and Agriculture Organisation of the UN (FAO), the International Monitoring Control and Surveillance Network (IMCS Network), and the International Criminal Police Organization (INTERPOL). While some groups exist specifically to address IUU fishing, others have wider objectives including economic development, security, law enforcement and sustainability. Indian Ocean bodies and organisations can be largely grouped into those with specific sub-regional focus, and those with wider regional coverage, and include operation in both informal and formal settings.

5.4.1 A patchwork of subregional collaborative clusters

Illegal fishing in the Indian Ocean occurs in both EEZs and ABNJ, which reflects the varied nature, impacts, and route to change that are needed for reform, at national, regional and international levels. However, ensuring collaboration across all such institutional levels, as well as geographically is challenging. Indeed, while governance frameworks across the region overlap on jurisdiction, regional and international bodies and organisations vary significantly in membership, operations and mandates. As outlined before, there are many initiatives and organisations with efforts and focus in the Indian Ocean, all working to combat illegal fishing. Whilst these efforts are warranted, and result in overall positive contributions, there is also no singular regional body that has membership of all coastal states in the Indian Ocean, resulting in fragmented regional cooperation and outcomes, and at times competition. While regional cohesion has improved, particularly across inter-governmental and NGO groups, regional management has been highlighted as an ongoing concern (Sinan et al., 2021; Sinan et al., 2022). However, it is important to remember that

international bodies, such as Regional Fisheries Management Organisations (RFMOs) are generally consensus-based decision-making bodies made up of member states with diverse and competing interests (Sinan et al., 2021). As such, understanding political and socio-economic constraints of member states on RFMO engagement will be critical for strengthening regional governance.

Overall, membership across regional inter-governmental organisations and RFMOs varies extensively. Only three countries and one regional block share membership of the four regional bodies (Australia, Japan, Korea and the European Union). Most coastal states from the Persian-Arabic gulf are not party to relevant RFMOs, not all Indian Rim countries are members of IORA and not are all Indian Ocean coastal states are members of SWIOFC. Overlapping and conflicting mandates between regional organisations have also been identified as a barrier to decision making processes in RFMOs. One case study points out that RECOFI, who manages species in the Caspian and Arabian Sea include neritic tuna species in their mandate. This species is also covered by the IOTC who shares membership with only one coastal state from RECOFI (Sinan et al., 2021). Inconsistent membership reduces the capacity of states to effectively engage with each other, and other stakeholders, to address illegal fishing and leads to broader problems such as gaps in the exchange of data and information and uneven implementation of MCS measures. For example, a 2022 report suggests that compliance failures of Bay of Bengal coastal states has exacerbated illegal fishing in the Bay (Faiyaz & Arif, 2022)

Encouragingly, regional cooperation has strengthened over time, particularly for East Africa. For example, The Regional Fisheries Surveillance Plan (PRSP) based in Mauritius conducts joint at sea surveillance patrols (Bergh, 2022). Likewise, the SADC regional MSCC assists member countries in coordinating regional fisheries MCS data and information sharing services, including a regional fishing vessel register and a monitoring system, provide regional fisheries surveillance, observer coordination services, Port State measures implementation support services, and fisheries law enforcement and legal support services, all designed to improve the capacity of national MCS in Member States, and the on flow positive effects in the region. The large majority of IUU incidents in the West Indian Ocean are detected through such regional task forces (Bergh, 2022). According to the interviewees, Fish-i Africa, an initiative established in 2012 by Stop-Illegal Fishing, and supported by the PEW Charitable Trusts, has had a massive impact on regional collaboration in the region. Fish-i-Africa unites eight East African coastal countries along the Western Indian Ocean through sharing and verification of information and resources.

Despite these substantial efforts and positive progress, a patchy framework of regional cooperation continues to present a challenge. There is much stronger institutional capacity in the West Indian Ocean than North Indian Ocean, which includes more on-ground organisations. However, the impact and success of regional patrols in the south is in part resulting in a push north. Therefore, it is important to note that increased effort and enforcement in one region may not remove the issue, so much as move it elsewhere. The multiple national and regional efforts appear to be influencing a general tendency towards improved quality and level of compliance with respect to data reporting, and collection. However, a potential reduction of illegal fishing from the industrial fishing, is not reflective of an overall reduction, with a significant increase from medium/semi-industrial vessels from some regional countries. However, even with increased oversight and focus, it is hard to disentangle changing effort from more knowledge and focus.

This patchy framework is not only a challenge at a regional level, but also for domestic frameworks in many countries around the Indian Ocean. More inter-agency cooperation is needed due to the ties between illegal fishing and other crimes such as the smuggling of illicit goods (drugs, illicit wildlife goods or weapons) and the trafficking of people. There is a higher prevalence of these issues in the West Indian Ocean as reported by Stop Illegal Fishing (2017). The lack of data-sharing and cooperation between domestic agencies, such an environment and labour, and fragmented legal approaches means that crimes are often unnoticed and unpunished. Regionally, there are improvements, such as Tanzania, who in 2015 established a Multi-Agency Task Team to deal with organised environmental crimes. Locally there is focus on national frameworks being strengthened, evidenced by, for example, such as South Africa's revision of legislation and potential re-establishing of a green court for marine judicial cases; Kenya's functioning coast guard and patrol vessels; through to increased capacity in staff, such as training of over 50 fisheries officers in Mozambique 2021, and Madagascar almost 90 new officers (Stop Illegal Fishing, 2021b). There are also examples in the northeast, including Indonesia who set up a Task Force on the Prevention and Eradication of IUU Fishing in 2015 that coordinated law enforcement efforts across multiple departments and agencies such as the Ministry of Maritime Affairs and Fisheries, Ministry of Transportation, the National Navy and the Financial Transaction Reports and Analysis Centre (Suherman et al., 2020).

5.4.2 Domestic fleets: a blind spot in management?

Much of the regional focus has been directed at ending illegal fishing perpetrated by foreign industrial fleets. This is understandable as industrial (foreign) fishing is crippling small-scale fishing and the communities that rely on them for livelihoods and food security. Additionally, as industrial fishing moves inshore there are significant consequences and impacts to local economies and ecosystems. However, there are concerns about the lack of political will to challenge some of the destructive aspects of domestic fisheries as well as international fleets. According to some experts, this is a bigger problem that illegal fishing by DWF vessels. Experts have reported multiple acts of illegal fishing perpetrated by domestic industrial vessels (e.g. fishing in closed areas by pole and line fishers, and the use of illegal anchored FADs).

Regionally, illegal fishing is perpetrated by three main offenders that might require different (political) strategies to address. 1) Domestic fleets (e.g., lobster/abalone fishing by national vessels); 2) Neighbouring/regional fleets; 3) International DWF fleets. This distinction is important to consider for future opportunities, as these offenders will have distinct modus operandi. The international industrial vessels might be more prone to mixing legal and illegal catch, and still offload; while neighbouring industrial vessels are more likely to offload at ports with weak oversight. Here it again must be noted that not reporting or underreporting catches is in cases considered illegal fishing, and it is, according to some experts, not an uncommon violation amongst vessels that fish in East-African EEZs.

5.4.3 Uneven regional capacity

Institutional capacity reflects the ability of an institution, or agency, to make change, to build capacity, to ride out challenges and buffer risk, and to enable effective planning for change (McNeeley, 2012). The range of capacity across the region varies, where some countries have world class infrastructure and well-developed national policy frameworks and in contrast, others may be information rich but lack capacity to implement such information into action. National initiatives, regional coordination, and international obligations, and the intersection and overlap between these, is a rapidly changing space, presenting a challenging picture for any nation to successfully manage. In many cases, complexity of obligations and global initiatives may present with complexity beyond reach for successful uptake and adoption by nations. Regionally, capacity has continued to impact on the ability to comprehensively monitor, control and surveil the region.

In contrast to other regions dominated by large scale industrial fishing, most of the Indian Ocean region is dominated by domestic small-scale fishing, and consequently, the sheer size and number of vessels, informal landing sites, and the human and technological resources required to monitor, control and surveil at such a scale presents a challenge for any agency. For example, along the east coast of Africa, there appears to be limited to no at-sea patrolling, particularly beyond the territorial sea (up to 12 nautical miles) due to capacity constraints. Regionally, there is minimal aircraft capacity for aerial surveillance, apart from the Regional Fisheries Surveillance Plan (*Plan Regional de Surveillance des Pêches*, PRSP) program that allows for occasional effort.

In any discussion of capacity, it is important to note the role of regional organizations and their impact. Regional groups have been instrumental in improving access and sharing of information, for example SADC, PRSP, IGAD and G16. These forums improve governance by providing an important platform for members to discuss, share and address regionally specific challenges. For example, the recent entry into force of the SADC Monitoring, Control and Surveillance Coordination Centre (MCSCC) was a direct result of a ten-year partnership between SADC countries and other stakeholders who shared a common goal of deterring illegal operators in their respective waters. The substantial progress made by the SADC was referred to during the SWIOFC 11th Session in the context of the regional implementation of Minimum Terms and Conditions (MTC) Guidelines for foreign fisheries access, demonstrating the impact that successful regional efforts have on emerging initiatives. A united approach has been particularly important for states with less economic and political power in comparison to DWF nations, who can often dominate the agenda of regional bodies (Stop Illegal Fishing and TMT, 2021). The G16, an informal group mostly made up of smaller coastal states in the Indian Ocean, has been working to address power inequalities in RFMOs through several avenues including training and preparing G16 negotiators for IOTC meetings. A recent study suggests that the role of the G16 has been important for improving representation of developing states during IOTC decision-making processes (Sinan et al., 2022). Established in 2001, the IMSC Network also plays a significant role in the region by supporting MCS, compliance and enforcement experts in Indian Ocean member countries to build knowledge and capacity.

In addition to these regional groups are other international non-profits such as TMT, Skylight and GFW. TMT has long-standing successful relationships in the region and continues to inform and support many agencies and initiatives. Skylight and GFW, also work to supply access to technical capacity and information through their platforms and bi-lateral regional collaborations. For

example, through partnerships with both TMT and GWF, Kenya is making strong investments in joint operation centres and vessel monitoring systems, upgrading monitoring capacity to satellite-based capacity and aerial patrols based on intelligence gathering.

5.4.4 Variable political will

Political will is critical to any sustained change and underpins the success of many national and regional efforts. The national importance of fisheries as a contribution to GDP, can be a significant driver for prioritisation of IUU fishing. This is well reflected in the region with island nations, many with high dependency and a significant reliance on fisheries for GDP, often leading the region with strong regulations, MCS capacity, funding and prioritisation. For example, in the Seychelles, where fishers contribute around 90% of the country's export revenue and employs over 10% of the population (Burroughs & Mazurek, 2019). The Seychelles Fisheries Authority have focused sustained effort on interception of illegal fishing by regional vessels in the Seychelles EEZ. In one case, in 2010 four Iranian flagged tuna vessels were apprehended by the authorities and found to be fishing without a license, and in 2013 a Malagasy vessel was found fishing in the outer islands of Les Amirantes (Marie & Bueger, 2021). These incidents, amongst other examples, have been identified as a key maritime security threat by the small island state. As such, Seychelles has been working steadily to improve its external capacity to manage illegal fishing in its water, including compulsory VMS monitoring for all large, registered vessels in the EEZ and both inter-agency and regional collaboration. In other cases, it is evident that IUU fishing is less of a national priority, with fisheries accounting for proportionately less to GDP, for example Pakistan where fisheries contributes than 1% to GDP (Shafique, 2017). However, despite fisheries being a relatively small proportion of GDP in Pakistan, there have been many important national efforts, for example a crew-based observer program and a by-catch mitigation project (including data collection system). For other nations, the prioritisation and capacity is in part due to the relative importance of marine fisheries in comparison to inland capture fisheries or aquaculture, as is the case for Kenya, where inland capture fisheries contributes over 80%, and marine artisanal fisheries just 5% (Njiru et al., 2021). This national importance and prioritisation has ongoing implications for the adoption and update of regulations, technology, and capacity.

However, regionally prioritisation is a result of more than just economics. In the case of Somalia, strong will, capacity and priority of MCS, and high production potential are hampered by

inconsistent governance and historical conflict (Glaser et al., 2019). This has resulted in substantial illegal fishing and the presence of many foreign fishing vessels in Somali waters. This is also a challenge elsewhere in the region, for example, a 2012 study on the links between political unrest, food security and unreported fishing in Madagascar suggests IUU fishing from foreign fleets, who target tuna-like species and sharks, steadily increased from 45,000 tonnes per year in 1990 to 80,000 tonnes per year by 2008. According to the data, most of the illegal catches were taken by Asian long-line fleets. The study also estimates that many of the known IUU fishing vessels targeting sharks in Southern and Western Madagascar had previously fished for Patagonian Toothfish in the Southern Ocean. The situation is attributed to an increase in fishing access agreements due to a withdrawal of bilateral aid and weak MCS (Le Manach et al., 2012).

Regional collaboration and information sharing is key when localized, domestic capacity is low. Such collaboration and information sharing has already been shown successful, as in the case of the RPOA-IUU sharing information for the vessel detained in Yemen, for the purpose of supporting the Port State Measures Agreement, which resulted in all regional countries closing access. According to members of the PRSP, regional surveillance missions have decreased the rate of serious offences of illegal fishing in the region since 2007 and could serve as an effective model for other areas in the Indian Ocean. Enabling regional collaboration on large scale issues would enable capacity and priority for countries to focus on MCS of domestic inshore fisheries.

5.4.5 Less intense management of food stocks

Illegal fishing has greatly reduced the biomass of not only the tropical tuna species but also the neritic species. Regionally, there is much focus on the tuna species. Whilst impacts and economics from such high value species are significant, given the regional reliance on other stocks for food and economic security, for example prawns, the impacts to the region from stock decline of these species is critical (David Russell, 2022). For example, evidence suggests billfish species have extensive social, economic, and cultural value in the western Indian Ocean but major discrepancies in data collection and monitoring across the region is hampering efforts to sustainably manage the species into the long-term (Kadagi et al., 2022). There are increasing calls for a better understanding of marine food security for coastal communities who rely on subsistence and small-scale fishing (Taylor et al., 2019). One study suggests that due to a lack of complete and accurate data, countries including Comoros, Mauritius, and Mozambique are undervaluing their economic dependence on

fisheries. In the case of Somalia, the value of the fisheries was underreported by 86.1% (Taylor et al., 2019). The appearance of low national dependency may be contributing to skewed management focus decisions or be used to justify access agreements. Additionally, at the national level, understanding the contribution of key species for coastal community livelihoods is critical for management interventions.

5.4.6 Persistent corruption

Corruption is pervasive across the region and a major barrier to progress (Stop Illegal Fishing 2021a). It can exist across all aspects of governance, and at all levels of engagement and operation, from international, to central and provincial through to district and village. For example, it is known to have occurred at the regional level, where experts reported certain IOTC countries being pressured to not install more stringent TAC for Yellowfin; through to national level issues such as state official facilitating illegal activities (Gastrow, 2001). For example, a 2019 case study of DWF operating in Mozambique and Seychelles highlighted concerns about IUU fishing in the region. The data in the study, which was based on interviews with governments, NGOs and the private sector, revealed Chinese and Taiwanese vessels were more likely to be perceived to be engaged in IUU fishing activities. In the Seychelles, this was attributed to Asian longline fleets offloading catch at sea, rather than Port Victoria, which was viewed as suspicious. While our interviews revealed the widespread belief that all foreign fleets were engaged in some level of IUU fishing, other studies suggest that threats and corruption from Chinese fishing operators had impacted the capacity of the Mozambique Government to properly implement compliance and enforcement measures (Yozell and Shaver, 2019). It is a complex issue, with social and economic drivers at the core. A 2014 case study of illegal abalone poaching in Hout Bay, Cape Town, identified a complex network of criminal actors involved with the various stages of the trade including poaching, processing and trafficking (Goga, 2014). Another study in 2022 by the Global Initiative against Transnational Organised Crime estimates illegal trade of abalone between South Africa and East Asia was valued more than US 890 million between 2000 and 2016. Corruption, income inequality and lack of international agreements for regulating the trade were identified as the key driving factors (Bondaroff et al., 2015). Corruption in bilateral access agreements has also been flagged as a concern for the region (Standing, 2008).

Corruption is in part facilitated by the patchy domestic frameworks. The lack of inter-agency cooperation and information-sharing allows bad actors to exploit gaps created by unclear division of responsibility between different jurisdictions (e.g., between maritime or customs authorities)

(Stop Illegal Fishing, 2021a). Previous reports have examined incidences of corruption in East African fisheries and revealed that in 50% of examined cases, corruption took place before fishing occurred (e.g., use of bribes to gain licenses) and often involved fishery agents (i.e., those who provide services for vessel owners such as hiring crew) (Stop Illegal Fishing, 2021a). Moreover, it is noted that corruption can prevent fisheries officers from adequately performing their duties, such as inspecting fishing vessels, in some cases body-worn cameras has been shown to mitigate this issue in the region (Stop Illegal Fishing, 2021b). Careful attention in the region, and further understanding into the causal pathways and cultural and social impacts of corruption, and its many routes of impact and influence will be key for the region to tackle and unravel.

5.5 Recent regional efforts

Despite numerous challenges, Indian Ocean countries are actively working to combat illegal fishing in their region and improve fisheries management at local, national and international levels. Here we highlight some of the positive efforts and outcomes from the key countries in our report.

Small Island Developing Countries (SIDS) in the West Indian Ocean are engaged in collaborative regional initiatives, have employed new and innovative methods to improve monitoring and surveillance in their large EEZs, and are working to improve regulatory and legislative frameworks for domestic fisheries management. In collaboration with ATLAN Space, TMT and GRID-Arendal, Seychelles is the first country in the region to utilise drone technology to monitor marine areas and hotspots for illegal fishing. In 2017, Seychelles was also one of the first countries to apply to the Fisheries Transparency Initiative and in 2023 became the first African country to ratify the WTO Agreement on Fisheries Subsidies. In addition, Seychelles has developed a Co-management Plan for its Mahe Plateau Trap and Line Fishery to support the demersal artisanal fisheries sector and a successful FAD management plan.

In 2022, Mauritius finalised the development of the countries' new fisheries bill which outlined new measures to tackle IUU fishing. According to the Mauritius government, the country is also working towards a new digital ship registration system and software to record artisanal fisheries catch data. Mauritius is active in the IOC Regional Fisheries Surveillance Plan (PRSP) alongside other SIDS in the region; Comoros, Madagascar, Seychelles and coastal states Tanzania and Mozambique. In 2022 Madagascar joined the SADC and became an official candidate country for the Fisheries

Transparency Initiative. Comoros has also strengthened efforts to fight illegal fishing practices in recent years. In 2021, with support from the SAPPHIRE project, Comoros fisheries authorities initiated a plan to raise awareness in the community about the impact of non-selective fishing gears and destructive practices such as dynamite fishing to help the country achieve its targets under SDG 14.6.1. In 2019 the Maldives enforced their National Plan of Action to Prevent, Deter and Eliminate IUU Fishing (NPOA-IUU) with plans to strengthen cooperation between Maldivian agencies, enhance trade and port measures and collaborate with other Member States to improve IOTC performance.

Coastal states in the East Africa region have also been working to deter illegal fishing through various means. In collaboration with Stop Illegal Fishing, South Africa has successfully used the Skylight platform to identify suspicious transhipping activities prior to the vessels entering the Port of Durban. As mentioned in the expert interviews, South African authorities are also hoping to re-establish the 'green court' which, according to stakeholders, was a critical tool for combatting marine poaching by criminal gangs.

In 2019, Kenya launched its new Coast Guard Service to intensify IUU fishing surveillance patrols and in 2022 ratified the Cape Town Agreement to protect crews and fisheries observers. Mozambique has developed several management and co-management plans for semi-industrial, industrial, and artisanal sectors while Tanzania's partnership with Sea Shepherd Global since 2018 has increased maritime security efforts. In 2021, Somalia drafted a new fisheries law to address loopholes in fishing license systems and improve compliance. Somalia also has a successful partnership with Fish-i Africa, which in 2016 resulted in the apprehension of an illegal trawler (GREKO 1) that had been fishing in Somalian waters for many years. Oman also appears to be taking a more proactive approach to combating illegal fishing in their region. In 2022, the country removed a fleet of vessels from their registry after investigations by the Environmental Justice Foundation revealed the vessels had been fishing illegally in the region.

Both India and Pakistan have introduced several innovative strategies to reduce by-catch. Examples in India include marine citizen science and awareness programs and smartphone apps to report by-catch incidents. Collaboration between WWF and fisheries authorities in Pakistan has seen the successful expansion of an observer program where officers are trained in by-catch identification and data collection. Additionally, a pilot program testing cetacean by-catch mitigation measures is reported to have significantly reduced incidents of dolphin by-catch in tuna gill net fisheries.

In 2019, Bangladesh announced their National Plan of Action to Prevent, Deter and Eliminate IUU Fishing (NOPA-IUU). Myanmar is also reported to have stepped up efforts to tackle illegal fishing. From 2020, all Myanmar's offshore vessels were required to have VMS installed. In 2023, an MoU between Vietnam and Thailand formalised previous cooperative efforts to deter illegal fishing in the region with increased exchange of information and resources between the two countries. Indonesia and Australia have also renewed efforts to reduce illegal fishing on their maritime border. A new agreement between the two countries increases coordinated surveillance, but also includes an alternative livelihoods development program to improve welfare for fishers from several Indonesia regions. The Australian Government is also trialling innovative technologies to prevent illegal fishing activities in two marine parks off the Western Australian coast. This includes uncrewed marine vessels, called Bluebottles, that can monitor large expanses of water for months at a time.

6 Summary

- For future research, efforts to ensure full participation of relevant countries will enhance study results and improve clarity of guidance that can be offered. Lack of responses can distort results and undermine advice; therefore, it is critical that studies are fully representative. It is recommended that future studies in the region ensure the participation of countries in the North Indian Ocean, particularly as this area has been highlighted as hotspots for illegal fishing in our report.
- It would be pertinent to use the results from this study to examine current approaches and policies at specific species, sectors and gears, and how those could be strengthened. For example, illegal fishers targeting species such as shrimps and prawns, groupers and coral reef fish were perceived as primarily breaking national legislation, suggesting more state-led efforts can be undertaken to mitigate illegal fishing for those species. This is opposed to species such as Yellowfin, Southern bluefin or swordfish, where international agreements were perceived to be breached. Pursuing efforts to improve MCS regionally will be important to both examples (e.g., build up the capacity to control drift FADs and ensure strong, equitable and transparent access agreements through domestic legislation), particularly if it can be done through existing regulations. Species-specific strategies are best focused on those species most targeted by illegal fishers, such as shrimps and prawns and Yellowfin tuna. Additionally, further efforts to combat illegal fishing can be targeted to gears perceived as being most frequently involved, such as trawlers or driftnets.
- Organisations such as SADC, E€OFISH, and Stop Illegal Fishing provide important examples of what effective regional cooperation can look like. This includes the pooling of resources, information and expertise across subregions for the benefit of countries with less capacity. States bordering the North Indian Ocean seem generally less connected with networks of fisheries cooperation, resulting in a considerable gap in monitoring and enforcement in the area.
- On a national level, efforts and resources can be streamlined and better coordinated between departments of the government. It is well established that illegal fishing and labour abuse are intimately intertwined, yet often communication and coordination between agencies can be challenging. This creates situations where fisheries officers are not properly trained or do not have appropriate powers to undertake action. Training and education opportunities to build human

capacity is important for identifying illegal behaviour and ensuring compliance. This is particularly important for MCS fisheries officers who work on the front line.

- Our report, and several other studies, highlight the prevalence of smaller vessels engaged in illegal fishing in the Indian Ocean. Therefore, tracking IUU fishing through singular methods such as AIS data may prove inadequate at capturing the full extent of the problem. Other approaches, as presented here, may prove useful to regional organisations who wish to supplement other methods of data collection in the region.
- One of the major challenges in the Indian Ocean is the overlapping areas of competence for RFMOs, as well as gaps in coverage of RFMOs for non-highly migratory species. Regional and international efforts to create a framework for addressing overlapping competencies and expanding the area of competence of RFMOs, could provide the basis for a better regulatory framework for fishing in the high seas, which in turn would also benefit coastal states. This constructive and practical way to address IUU fishing would be highly beneficial to the region.
- Strengthening cooperation across ocean basins and looking to other regions for innovative ideas may be beneficial for the Indian Ocean. For example, the Pacific Ocean and the Indian Ocean share several characteristics such as small island countries with large EEZs and a reliance on highly valuable tuna resources. Similar challenges may provide opportunities for collaboration with organisations such as the Pacific Fusion Centre and the Pacific Islands Forum Fisheries Agency (FFA).
- This report may offer regional organisations an important starting point for further study into issue areas that have been highlighted. This study had a broad scope and therefore does not offer in-depth analyses regarding species, areas or sectors of interest. For example, more granular studies on the biological status and management of stocks important for food security (e.g., shrimps and prawns) in areas where large artisanal sectors operate would be beneficial to countries reliant on Indian Ocean fisheries. This would be instrumental for localised management interventions, as the strength of this report largely lies in its ability to give a broad overview of the status of illegal fishing across the region.

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