



Photo by: Francisco Blaha

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Revealing the Supply Chain at Sea: A Global Analysis of Transshipment and Bunker Vessels

Monitoring of transshipment activity can be used to better understand the world's distant water fishing fleets

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Global Fishing Watch

Tony Long, chief executive officer

Project team

Nate Miller, lead author

Tim Hochberg
David Kroodsma
Hannah Linder
Jaeyoon Park

About this report

This report reveals the network of support vessels that makes it possible for distant water fishing fleets to operate far from home. Transshipments at sea between carriers and fishing vessels may enable the transfer of illegal, unreported and unregulated seafood product and, by allowing fishing vessels to remain at sea for extended periods of time, can foster conditions that permit forced labor to occur. Global Fishing Watch processed billions of vessel positions based on automatic identification system, or AIS, data to identify meetings at sea between fishing vessels and bunker and carrier vessels, as well as the ports these vessels visited. This information was then analyzed to determine how the global network of support vessels can help indicate risk of forced labor on board fishing vessels.

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Overview

Many fishing fleets, especially those traversing the high seas, operate far from their home ports and stay at sea for months on end. To more efficiently get fish to market, these vessels will rendezvous with large refrigerated cargo vessels, commonly known as fish carriers or reefers, and offload their catch so they can continue fishing. These vessels may also refuel at sea by meeting up with tankers, or bunker vessels, allowing them to avoid a trip back to port. This network of transshipment and support vessels helps the world's distant water fleets operate more efficiently across large swaths of ocean in some of the highest value fisheries in the world,¹ including the global tuna fishery worth US\$42 billion (Pew, 2020).

While economically advantageous, transshipment can enable bad actors. Vessels that might be denied access to ports because of past infringements can instead offload their catch at sea, creating an opportunity for illegally caught fish to be combined with legal catch (Environmental Justice Foundation, 2013). In the western and central Pacific Ocean alone, at least \$142 million worth of tuna and tuna-like products are lost in illegal transshipments each year (MRAG Asia Pacific, 2016). Transshipment has also been linked to weapons, drug, and human trafficking and may allow captains to keep their crew at sea indefinitely in de facto slavery (McDowell et al., 2015).

Bunker vessels have historically received less attention than carriers—they are not often mandated to be registered to regional fisheries management organizations (RFMOS)²—but they fulfill a similar role by enabling vessels to stay at sea indefinitely. While bunker vessels have less oversight than transshipment vessels, according to some research, their activity can actually help identify illicit networks operating across the ocean (Ford et al., 2018). Publication of vessel identification, authorization and tracking data will allow stakeholders to use transparency to help differentiate legal, sustainable activity from that which is potentially illegal, unreported and unregulated (IUU).

Global Fishing Watch seeks to shine a light on transshipment—one of the most opaque practices in the commercial fishing industry—using transparency to drive fair and sustainable management of marine resources. In an effort to better understand how distant water fishing fleets are supported, we analyzed vessel tracking data over eight years, identifying vessels and ports that played significant roles.

This report presents an expanded database of transshipment and bunker vessels and reveals the distribution of their activity, showing which fleets and vessel types engage in transshipment activity and which ports they primarily use. It also provides a breakdown of activity, indicating what types of events likely support tuna fishing as opposed to fleets targeting other species.

The analysis goes on to provide an initial assessment of potential networks supporting forced labor in pelagic longliners, building on recent research that models the risk of forced labor (McDonald et al., 2020). Although the results of this research require further investigation and validation, the study found that as much as half of the pelagic longline fleet has an elevated risk of forced labor.

¹ It should be noted that there are also some forms of smaller-scale transshipment, such as the exchange of fish between fishing vessels, whose activity can be substantial in some regions (FAO Transshipment Report). This report, however, focuses only on large-scale transshipment and bunker vessels that engage in activity away from port.

² We note that bunker vessels are listed on the WCPFC Record of Fishing Vessels and are included in ICCAT registry, though under the broad label of non-fishing vessels. Though there are generally fewer explicit regulations for bunker vessels, the Parties of the Nauru Agreement (PNA Circular No: 2019-11) have recently expanded a set of regulations around bunkering activity.

Moreover, the vessels that had a high risk of forced labor were far more likely to engage in transshipment than those that did not. Harnessing satellite technology, we analyze which transshipment vessels these higher-risk longliners meet up with and highlight how this risk may be concentrated in some specific networks in the ocean.

The report outlines four key findings:

- 1. Between 2012 and 2020, a total of five fishing entities account for the majority of the 24,000+ encounters with carrier vessels and 14,000+ encounters with bunker vessels.** To ascertain these numbers, we developed the first ever public, global dataset of fisheries support vessels that includes both carrier and bunker vessels. The database includes 1,350 carrier vessels and 963 bunker vessels. We further identified a subset of these vessels that may support high seas tuna fleets (105 carrier and 119 bunker vessels). Between 2012 and 2019, we identified 24,760 encounters with fishing vessels by carrier vessels and 14,585 encounters with bunker vessels. These events are widespread across the ocean, but are mostly carried out by a few fishing fleets, including the Russian Federation (Russia) (54 percent of carrier encounters, 25 percent of bunker encounters), China (17 percent and 19 percent respectively), Republic of Korea (10 percent and 6 percent respectively), Chinese Taipei (9 percent and 12 percent respectively) and Japan (5 percent and 4 percent respectively).
- 2. Discrepancies between the number of encounters and number of loitering events suggest transshipment activities whereby fishing vessels were not broadcasting AIS.** Using an expanded vessel database, we applied our model identifying loitering events to reveal where carrier vessels may be transshipping with fishing vessels that are not broadcasting their locations. Between 2012 and 2020, we identified 78,493 loitering events by transshipment vessels and 78,512 loitering events by bunker vessels that were unmatched to comparable encounters. However, between 2012 and 2020, the ratio of encounter to loitering hours increased from 0.05 to 0.81 even though total loitering did not increase, suggesting that more vessels are broadcasting their GPS positions.
- 3. A small number of ports are integral in supporting the transshipment network at sea.** While distant water fleets visit ports all over the world, there are a handful that are particularly integral to the network of transshipment. Half of transshipped fish, regardless of where it is caught, travels to only five ports; about 90 percent travels to only 30 ports. Monitoring and control operations and implementation of port State measures in these ports play an important role in combating IUU fishing and increasing oversight of transshipment both at sea and in port.
- 4. There is a high risk of labor violations in longline vessels that transship.** Drawing on recent research, we find that drifting longliners frequently engaged in transshipment activity have a higher risk of harboring forced labor on board. Moreover, the majority of voyages involving transshipment vessels that support drifting longliners had at least one encounter with a high-risk vessel. By analyzing relationships between vessels and port visits, we identify networks supporting these higher-risk vessels.

Using key datasets and analysis, this report builds on previous work by Global Fishing Watch (Miller et al., 2018; Boerder et al., 2018) and includes a more focused look at tuna fleets, bunker vessels, and transshipment activity associated with vessels with a high risk of forced labor. The methods

used in the report have also been implemented in recent transshipment [analyses](#) provided to RFMOs by Global Fishing Watch and The Pew Charitable Trusts. Drawing on these methods, Global Fishing Watch has developed an online [portal](#) that visualizes the activity of these carrier vessels to highlight potential transshipment activity in an interactive way.

Tracking vessels with satellite technology

The vessel tracking data used in this report comes from automatic identification systems (AIS) transmissions, which broadcast vessels' GPS positions over radio to avoid collisions with other nearby vessels. AIS devices transmit a unique maritime mobile service identity (MMSI) number as well as a vessel's position, speed, course and identity. The use of AIS was first mandated in 2002 under the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea. The requirement pertains to all vessels over 300 gross tons engaged in international voyages (landing in a port outside of the vessel's flag State), though fishing vessels are generally exempt. Although AIS was initially designed to communicate with other vessels in line of sight, governments and private companies have recently installed coastal receivers and launched satellite constellations that can record AIS messages, meaning it is effective to track vessels globally.

Global Fishing Watch receives AIS data from two providers, Orbcomm and Spire, and applies machine learning algorithms to determine vessel class (combining the results with vessel registries where available) and, for fishing vessels, when and where they fish. These algorithms classify vessels into specific types—cargo, tanker, purse seiner, trawler—and estimate the vessels' size, including engine power, length, and gross tonnage, based on their movement patterns. For those identified as fishing vessels, a second algorithm determines a vessel's given position when it was fishing and provides a high-resolution, global footprint of fishing activity.

For a more detailed description of how fishing effort is measured by AIS, see [“Tracking the Global Footprint of Fisheries”](#) (Kroodsma et al., 2018) or [The Global Atlas of AIS-Based Fishing Activity](#) (Taconet et al., 2019). Limitations of AIS include poor satellite reception in some regions, failure to broadcast and lack of universal use. These limitations are outlined in detail in The Global Atlas.

Fishing fleets that transship or bunker at sea

Most fishing vessels operate close to shore, making it unnecessary to transship their catch before it is landed or meet up with bunker vessels to refuel. In general, the farther from shore or port a vessel operates, the more likely it is to transship and rely on support vessels.

Pelagic fisheries, where many of these long-distance fleets operate, are dominated by tuna and tuna-like species, such as sharks and billfish. Pelagic fleets also target squid, and these fleets rely heavily on transshipment vessels. Global Fishing Watch's database identifies the gear used by fishing vessels, making it easy to identify the key gear types engaged in transshipment and bunkering activity, which include trawlers, light-lure vessels—vessels that use light at night to fish—most of which are squid jiggers, tuna purse seiners and drifting longliners.

Tuna and tuna-like fisheries

A significant portion of drifting longliners and tuna purse seiners in the Global Fishing Watch dataset have at least one encounter, or meet-up, with a bunker or carrier vessel (Figure 1). About half of the fishing activity of drifting longliners in the dataset was carried out by vessels that had at

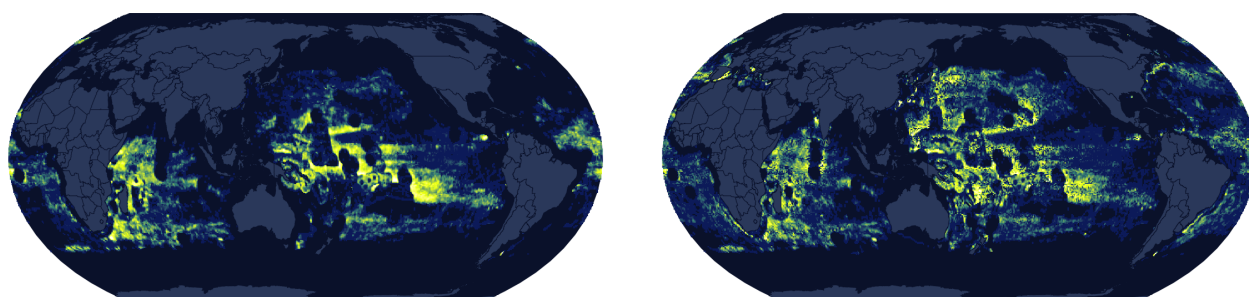
least one encounter—60 percent of purse seine activity was by such vessels. Purse seiners, however, generally only meet with bunker vessels while at sea; in contrast, drifting longliners largely meet up with both bunker and transshipment vessels.

These vessels target tuna and tuna-like species. With five million metric tons caught globally per year (ISSF, 2020; Pew, 2020), tuna is the most important catch by value, worth a total of \$40.8 billion in 2018 (Pew, 2020). While drifting longliners exceed the purse seine fleet in both the number of operational vessels and area fished, they catch much less tuna. Globally, about 65 percent of tuna is caught by purse seiners, and only around 11 percent is by drifting longliners (Mosteiro Cabanelas et al., 2020).

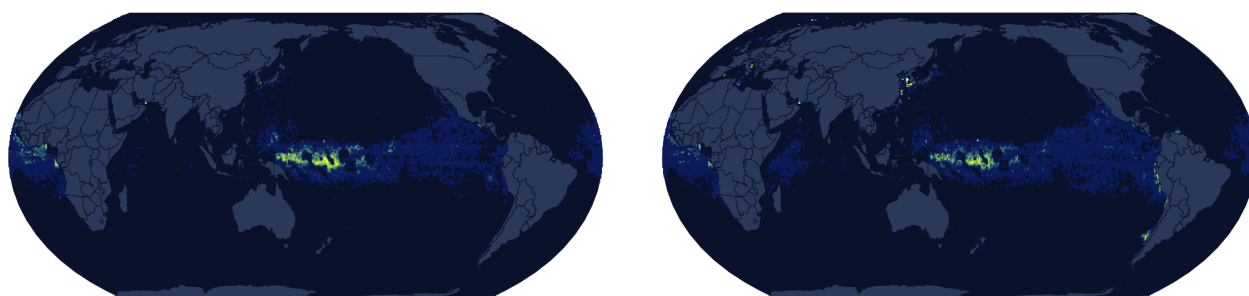
Figure 1

Fishing Activity of Vessels Targeting Tuna and Tuna-like Species in 2019

Drifting Longlines



Tuna Purse Seines



Hours per 1000 km² 10 100 1000

The left column represents fishing activity by vessels that were involved in encounters and the right column represents fishing activity by all vessels.

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Light-lure fisheries

Light-lure fisheries, or fisheries where vessels use bright lights at night to lure fish to the surface, are dominated by squid, although a few other species, such as Pacific saury, are also significant. Global Fishing Watch tracked the light-luring fleet and found that it operates largely on the high seas, relying heavily on bunkering and transshipment; at least 80 percent of their fishing activity in the dataset were by vessels that relied on these large supply vessels (Figure 2). The actual figure may be higher because many of the vessels in this fleet frequently disabled their AIS, meaning that some

encounters may not be recorded. The exact amount of catch belonging to this fleet is unknown, partially because in at least two regions—the northern Indian Ocean and southwest Atlantic—there is no RFMO managing these species. But according to a [report](#) from the Food and Agriculture Organization of the United Nations, the total catch is estimated to be in the hundreds of thousands of metric tons per year (Mosteiro Cabanelas et al., 2020).

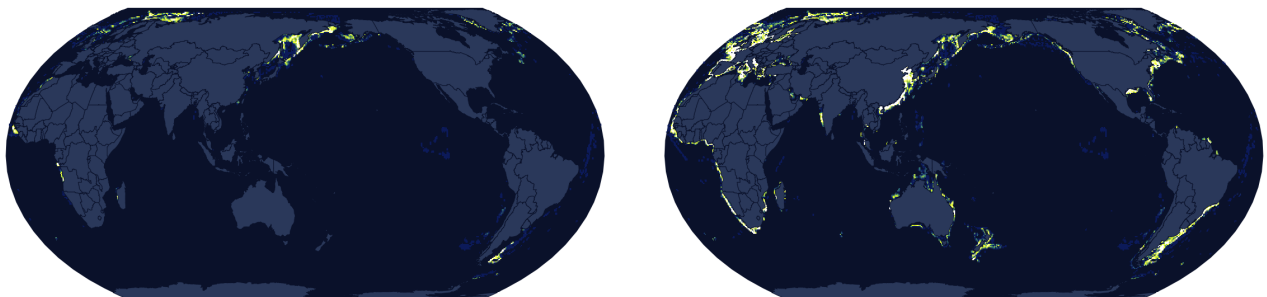
Trawl fisheries

Trawl fisheries mostly involve demersal fish—fish that can be found near or on the bottom of the body of water they inhabit—and are likely responsible for more than one-third of all marine fish caught (Watson, 2017). However, a significant portion of trawl vessels are not represented in the dataset because vessels operating near the coastlines in many countries do not broadcast AIS as frequently as pelagic vessels. Because most operate close to their home port, trawlers also have less of a need for transshipment or bunker vessels. In the Global Fishing Watch dataset, AIS data shows that only 5 percent of trawler fishing activity was by vessels that had at least one at-sea encounter with transshipment or bunker vessels. These fleets operated mostly in far northern or southern waters, or along the African coastline, with vessels flagged to Russia being responsible for the majority of trawler activity that relied on support vessels (Figure 2).

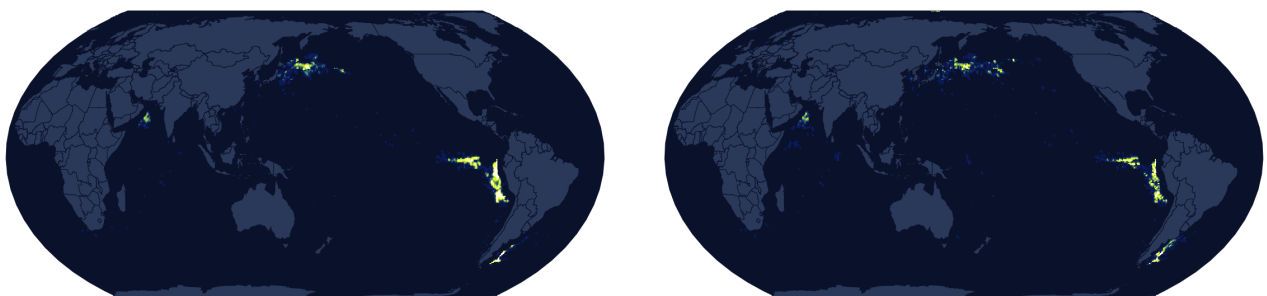
Figure 2

Fishing Activity of Vessels not Targeting Tuna and Tuna-like Species in 2019

Trawlers



Light-Lure Fishing



Hours per 1000 km² 10 100 1000

The left column represents fishing activity by vessels that were involved in encounters and the right column represents fishing activity by all vessels.

Meetings at sea: Encounters and loitering events

AIS data cannot confirm if goods or people are exchanged when vessels meet, but it can identify potential transshipments or bunkering events at sea. This report utilizes improved methods to identify two types of behavior at sea: two-vessel encounters and loitering events.

Two-vessel encounters

The methods for identifying encounters at sea are described in [Identifying Global Patterns of Transshipment Behavior](#). Encounters represent locations where a fishing vessel and a neighboring vessel are continuously within 500 meters from one another for at least two hours and traveling at less than two knots, while at least 10 kilometers from an anchorage. The number of carrier vessels involved in fishing vessel encounters has regularly increased each year until 2017 (Figure 3), as did the number of carriers meeting drifting longliners and tuna purse seiners. Since 2017 the number of carriers involved in encounters has remained steady or declined. Slightly fewer bunker vessels are involved in encounters with fishing vessels though the overall number of active bunker vessels in the dataset has generally increased (Figure 3).

Loitering-events

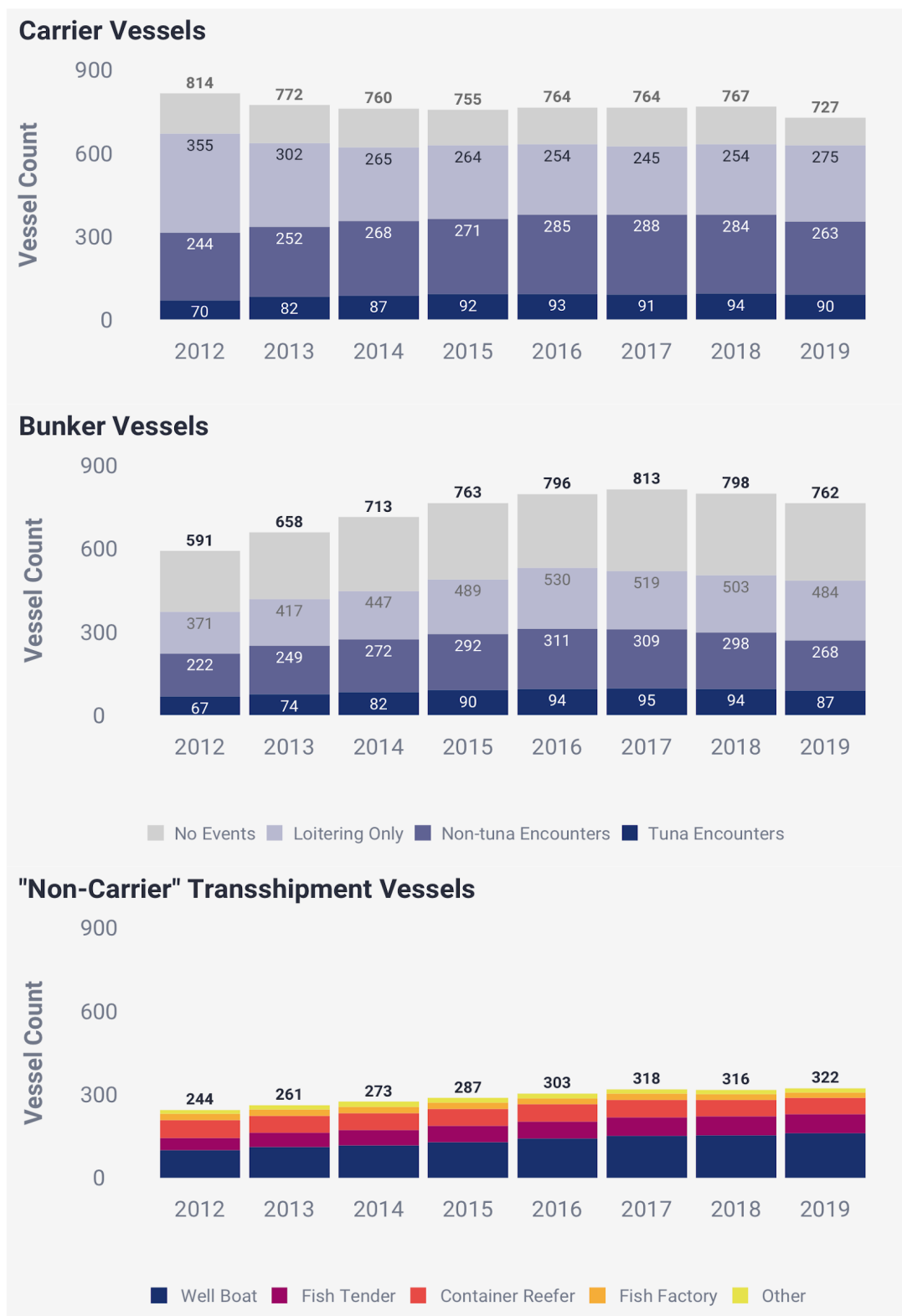
When support vessels meet with a fishing vessel at sea, they move slowly, sometimes motoring steadily into the waves or wind to facilitate an easier exchange. Because transshipment vessels and bunker vessels are much larger than fishing vessels and are often subject to different regulations, almost all of them carry high-quality AIS devices, which are rarely turned off. Fishing vessels, in contrast, may not always be outfitted with AIS or have it turned on and, as a result, may not be visible in the Global Fishing Watch dataset. This results in the appearance of a supply vessel moving slowly as if to bunker or transship, but no other vessel is visible. To address this behavior, we developed two models to identify loitering at sea. All encounters also include a loitering event by a supply vessel. Loitering events that do not include an encounter in the AIS data may either be a supply event with a fishing vessel that is broadcasting, or merely the supply vessel waiting until its next task.

Database of support: Transshipment and bunker vessels

To develop a database of refrigerated cargo vessels capable of receiving catch and bunker vessels equipped to refuel fishing vessels at sea, we used three complementary methods that were built on by those described in Miller et al. 2018, drawing on: official vessel registries; Global Fishing Watch's vessel classification algorithms, which identify vessels based on their behavior; and a manual review of vessels that had encounters with other vessels at sea (see appendix for full methods).

Figure 3

Unique Support Vessel Counts by Year



Stacked bars in the graphs labeled as carrier vessels and bunker vessels represent those vessels that have encountered drifting longliners and tuna purse seiners (tuna encounters), vessels that have only met other fishing vessel classes (non-tuna encounters), vessels that only exhibited loitering events, and vessels for which we detected no events. Bold numbers at the top of each bar represent the total number of vessels accounted for, while intermediate numbers represent the breakdown for each activity. The total database contains 2,100 transshipment vessel MMSI numbers and 1,400 bunker vessel MMSI numbers.

These vessels represent an important open-source dataset of transshipment and bunker vessels, critical for increasing the transparency of at-sea supply chains. We identified about 700-800 transshipment vessel MMSI numbers and about 600-800 bunker vessel MMSI numbers that were active each year from 2012-2019. We restrict our analysis to carrier vessels (Figure 3), which possess derrick and/or crane superstructures and may transship at sea and/or in port. However, the complete database referenced in this report includes additional vessels capable of transporting fish and fish products, such as:

- **Well boats**, which are primarily associated with live-fish transport for aquaculture operations.
- **Fish tenders**, which often transport smaller quantities of fresh or frozen fish to port or processing facilities.
- **Fish factories**, which serve as mobile, floating processors for a given fishing fleet.
- **Container reefers**, which primarily transport cargo, including fish, in refrigerated shipping containers.

This report focuses specifically on carrier vessels and bunker vessels (Figure 3), as they represent a critical link in the international trade and transport of fish and fish products, but their activities are difficult to monitor, manage and regulate. “Non-carrier” transshipment vessels tend to operate within national jurisdictions—fish tenders and well boats often operate close to shore and generally do not undertake international voyages or typically load/unload cargo within ports where monitoring is less onerous.³

Transshipment and bunker vessels change their identity frequently. Roughly 45 percent of carrier vessels and 30 percent of the bunker vessels in our database changed aspects of their identity between 2012 and 2019, altering their name, flag State, call sign or MMSI. Some vessels changed these aspects of their identity up to three times. These shifts in identity make it challenging to count the true number of vessels, as a single vessel may, over time, have multiple names, MMSI, or flags.

For transshipment and bunker vessels, IMO numbers often help to uniquely identify a vessel, though some smaller vessels are not required or are not eligible to register for one (Pew, 2019). Of the 2,152 unique MMSI found in the carrier vessel dataset (across all years), a total of 2,116 are associated with an IMO number. The bunker vessel dataset contains 1,416 unique MMSI, with 1,385 associated with an IMO number. This translates to 98 percent of the vessels in both groups having IMO numbers. Based on IMO numbers, the carrier vessel dataset contains 1,005 distinct hulls and the bunker vessel dataset contains 962 distinct hulls.

Not all vessels within the carrier and bunker databases have encounters with other vessels. Figure 3 also shows the number of carrier and bunker vessels active each year that have engaged in transshipment behavior at some point in time. Less than half of the vessels in the database appear to have met with a fishing vessel in a given year. Among the ships that met with fishing vessels, about a quarter interacted with purse seine or longline vessels that may target tuna. For carriers that have no observed encounters, 65-75 percent had at least one loitering event, leaving roughly 100-150 of the active carrier vessels each year with no clear at-sea transshipment-like behavior. One explanation for this finding is that these carriers operate as shuttles, perhaps even playing critical roles in regional distribution (described in a recent [report](#) by the West Africa Task Force), but any transshipments occur within ports. Only 40 percent of the bunker vessels with no encounters had at least one loitering event, meaning that the remaining vessels appear to have never met up with

³ We recognize that continued efforts are necessary to strengthen port state controls globally.

other vessels at sea. It may be that these approximately 250 vessels transport fuel between ports or provide refueling services in port rather than at sea.



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To more efficiently get fish to market, fishing vessels will rendezvous with large refrigerated cargo vessels, commonly known as fish carriers or reefers, and offload their catch so they can continue fishing.

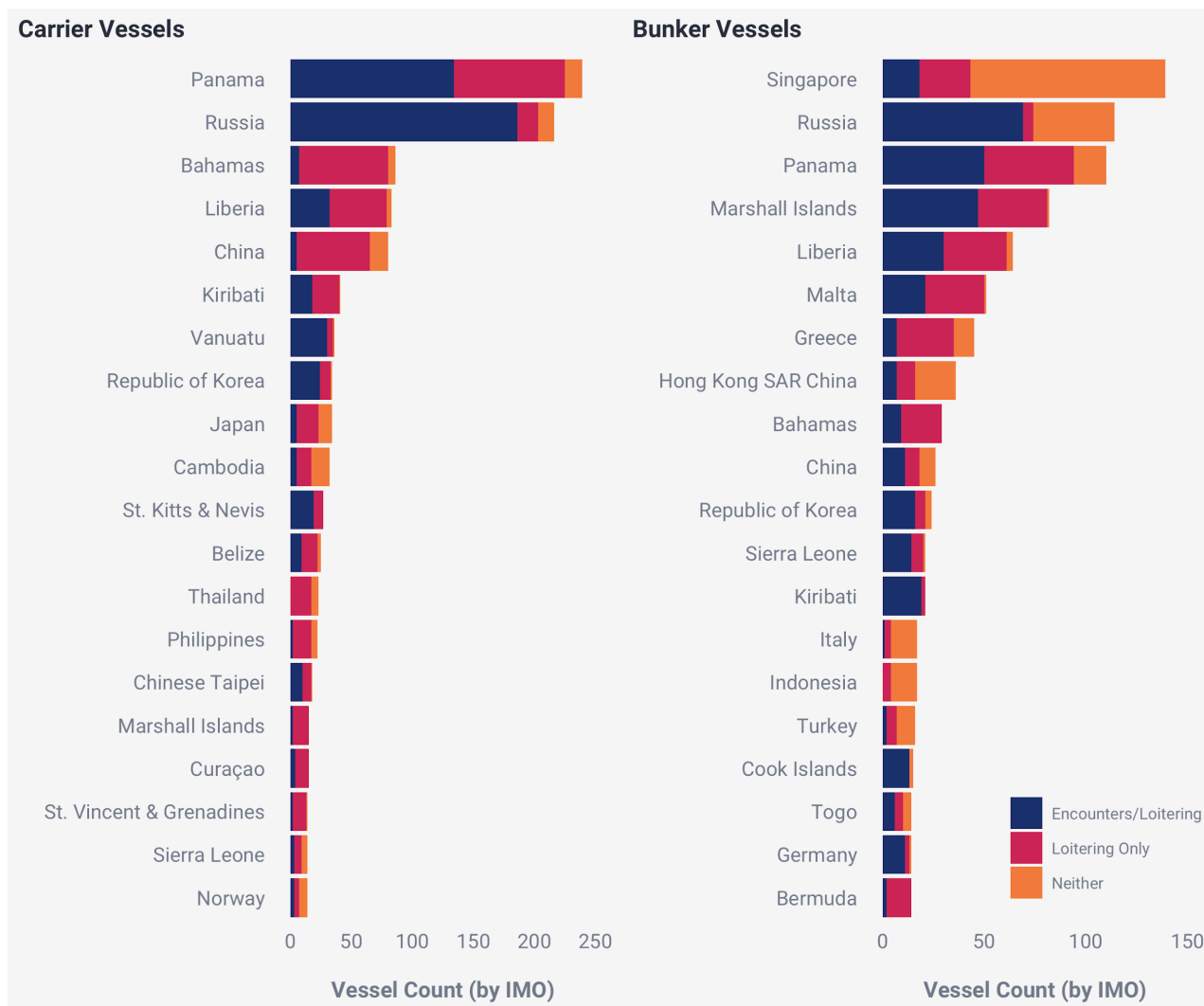
Flags of support vessels

Panama and Russia have the greatest number of registered carrier vessels; vessels flagged to Panama are more likely to be involved in loitering events only—a potential transshipment event where fishing vessels are not broadcasting their AIS data. Carriers flagged to China and the Bahamas are also more often observed in loitering events than two-vessel encounters (Figure 4).

Bunker vessels are often flagged to Singapore, Russia, Panama, and the Republic of the Marshall Islands (Marshall Islands), though vessels flagged to Singapore do not engage in significant transshipment-like behavior, either encounters or loitering. And some carrier and bunker vessels are not observed to be involved in any loitering events or encounters at all. This may mean that these vessels do not engage in at-sea transshipment or refueling operations (perhaps only transshipping in port) or their at-sea transshipment operations are not captured by our current algorithms.

Figure 4

Most Common Carrier and Bunker Vessel Fleets



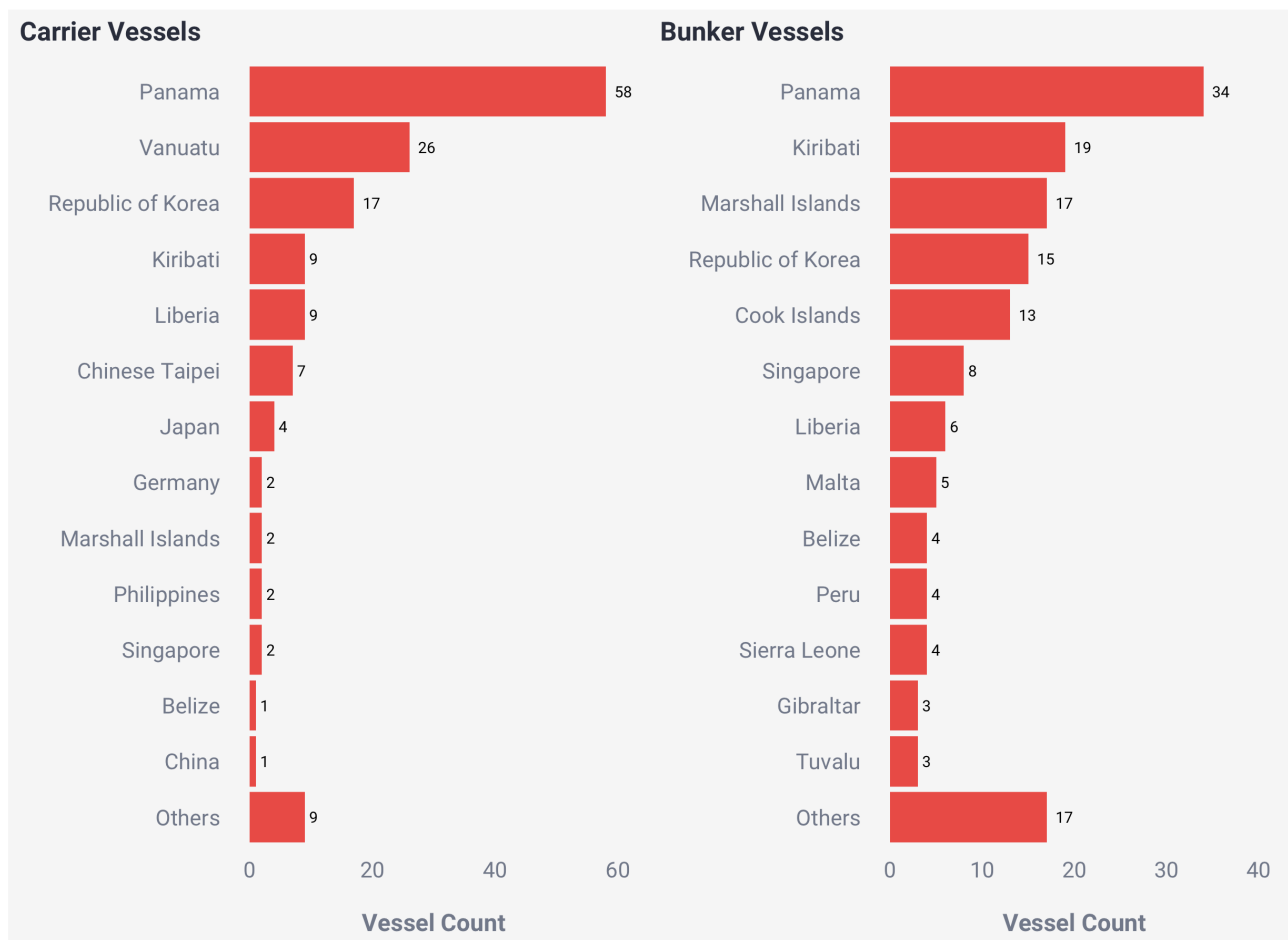
Number of vessels by flag State involved in encounters, loitering events or neither.

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A closer consideration of carrier encounters with vessels primarily targeting tuna—whether drifting longline or tuna purse seine vessels—shows that carriers have a slightly different flag State distribution. Carriers are commonly flagged to Panama, Vanuatu and the Republic of Korea, while encounters involving Russian-flagged carriers are considerably less common. A similar pattern arises for bunker vessels registered to Panama, Kiribati, Marshall Islands and the Republic of Korea, which are more frequently involved in encounters with possible tuna vessels (Figure 5).

Figure 5

Support Fleets Associated with Vessels Targeting Tuna and Tuna-like Species



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Quantifying at-sea support

Wider adoption of AIS now allows us to identify a clearer picture of the scope and distribution of the supply chain at sea. Over the past eight years, the number of fishing vessels broadcasting AIS has increased substantially, largely because changing regulations have required more vessels, including smaller ones, to carry the device—the number of vessels broadcasting AIS positions has increased 10-30 percent each year from 2014-2017 (Taconet et al., 2019).

In contrast, the number of carrier and bunker vessels broadcasting AIS has stayed roughly constant, as these vessels, which are generally much larger, were already mandated to broadcast using AIS as of 2012. As a result, even though current bunker and carrier vessel activity is fairly similar to what it was several years ago, it appears that the number of hours spent in encounters with fishing vessels has increased (Figure 6). This increased use of AIS also means that AIS is a far more useful tool to monitor transshipments than it was a few years ago. These data suggest that if loitering hours by these reefers is roughly equivalent to the total hours spent in transshipments (at least not likely higher), then AIS in 2018 and 2019 likely captures the majority of transshipment activity. In 2017 and earlier, the ratio was far lower. For bunker vessels, the ratio between encounters and loitering

hours is quite low. This suggests that either bunker vessels are meeting with a greater number of vessels operating without AIS—also known as “dark vessels”—or that loitering events by bunker vessels are less likely to represent refueling of fishing vessels.

The number of loitering hours, which is likely to better represent the total amount of potential transshipment, does not vary too much over the time period but does show a downward trend in 2018 and 2019. The transshipment vessels in this study have about the same use of AIS in 2012 as they do today, so we do not expect the loitering hours by these transshipment vessels to be affected by changes in AIS use.

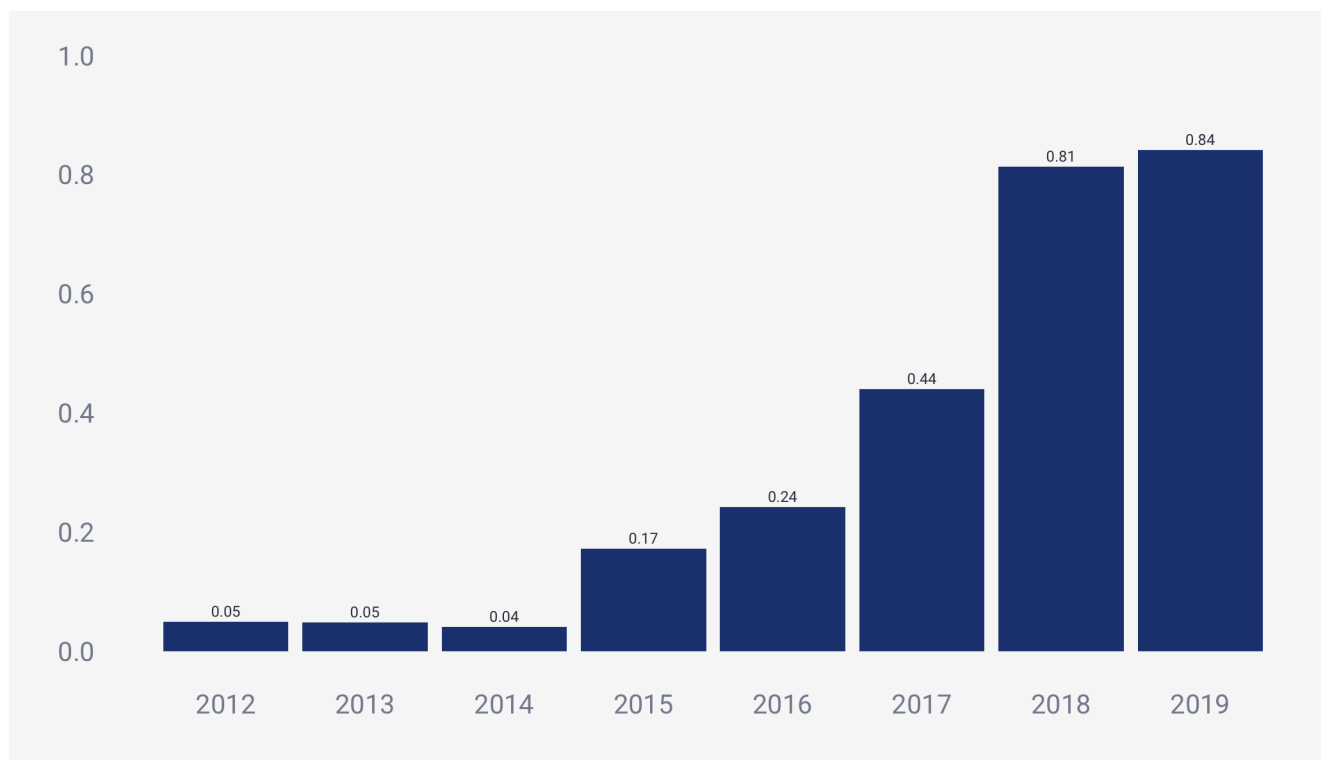
Figure 6
Total Hours of Encounters and Loitering Events by Year



Total number of hours include aggregated hours of all encounters and loitering events. Loitering events were capped at 48 hours.

Figure 7

Ratio of Total Encounter Hours to Total Loitering Hours for Carriers by Year



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The growing ratio of encounter hours to loitering hours (Figure 7) serves as another indicator that fishing vessels are increasing their adoption of AIS and that we are therefore more capable of identifying both vessels involved in potential transshipments.

Spatial footprint of support: Encounters

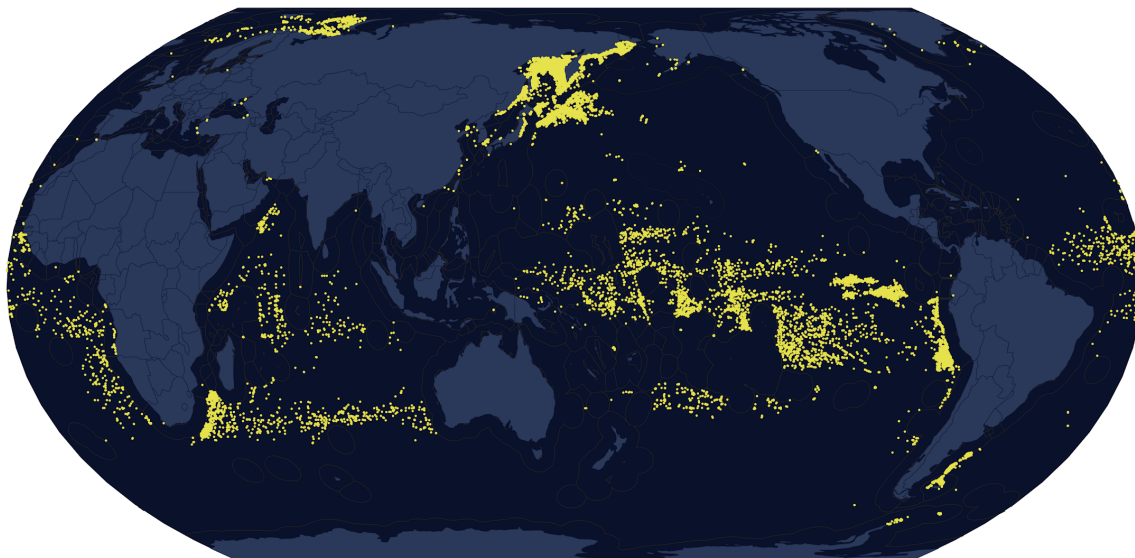
The spatial footprint of encounters between carrier and fishing vessels has been reported on previously (Miller et al., 2018), but it is provided in this report with an additional two years of data.

The following maps provide a comparison of encounter events involving fishing and bunker vessels (Figure 8). The similarity in the footprints between bunker and carrier vessels is striking but two differences remain. There appears to be a greater number of encounters between bunker and tuna purse seine vessels in the western and central Pacific, which are generally prohibited from meeting carrier vessels to transship; there are fewer encounters taking place in the northwestern Pacific that are carried out by bunker and fishing vessels targeting squid, Pacific saury or chub mackerel.

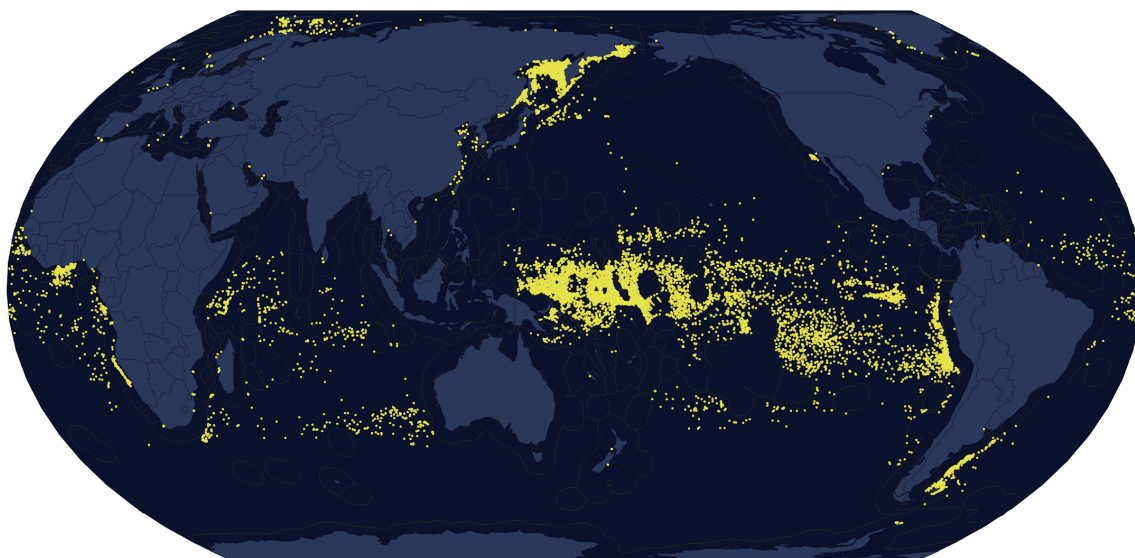
Bunkering activity within the Russian Far East and Southwest Indian Ocean is also reduced, but it remains unclear if this is due to reduced dependence on bunkering in general or whether bunker vessels that operate in this region are missing from the database. It is also possible that spatial patterns reflect patterns of AIS use, AIS reception, and AIS tampering. However, the transshipment vessels found in this region rarely disable their AIS. According to an analysis by Global Fishing Watch, AIS gaps—the time between consecutive AIS positions—longer than 24 hours only account for about 3 percent of carrier vessels' time at sea. Many of these gaps can likely be explained by traveling through areas of very poor AIS reception, such as when transiting through Southeast Asia (see Figure S1 for reception quality).

Figure 8
Encounters Involving Carrier and Bunker Vessels, 2012-2019

Carrier Vessels



Bunker Vessels



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Spatial footprint of support: Fishing vessel class

Carrier vessels

The global footprint of encounters demonstrates the ubiquity of carrier vessels' transshipment behaviors in much of the world's ocean. When separated by fishing vessel class, however, it is clear that regional patterns are driven by specific fishing gears. Encounters involving trawlers generally occur close to shore, with the majority occurring in Russian waters (Figure 9, *trawlers*) and primarily involving Russian-flagged vessels (Miller et al., 2018). Regions around South America and the

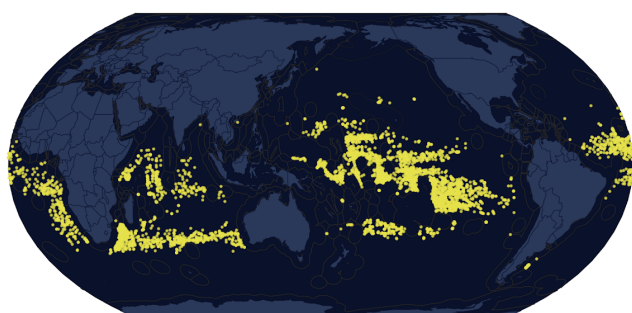
Antarctic Peninsula, West Africa, and the Barent Sea also show encounters involving trawlers. Drifting longline encounters are commonly found to take place in tropical and subtropical regions of the world's ocean, particularly in areas on the high seas. And carrier encounters with fishing vessels that target squid or use light-luring methods, such as jigger and dip-net vessels, have a clearly differentiated footprint in the high seas in the Northwest and Southeast Pacific Ocean, Southwest Atlantic Ocean, and the Northwest Indian Ocean (Figure 9, *light-lure fishing*).

Encounters involving large purse seine vessels targeting tuna are relatively rare, especially in the Pacific Ocean where at-sea transshipment by purse seine vessels is prohibited by the Western and Central Pacific Fisheries Commission (WCPFC). The few events that do occur predominantly take place within national waters of small island developing states (Figure 9, *tuna purse seines*). While these events are of interest, given the ban on at-sea transshipment and the 100 percent observer coverage on purse seiners in the WCPFC Convention Area, many of these events may represent non-transshipment activities such as provisioning of salt, spare parts, and the exchange of crew members (Seto et al., 2020). Finally, encounters between carrier vessels are not uncommon (Figure 9, *carrier vessels*), especially within the Russian exclusive economic zone (EEZ) and the high seas near Peru and west coast of Africa. Whether these encounters involve the exchange of fish, provisions, fuel or crew is not clear.

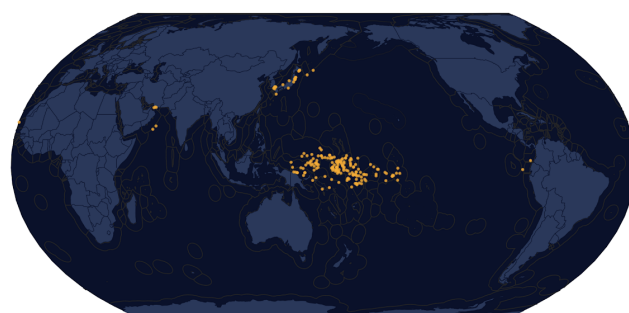
Figure 9

Carrier Vessel Encounters by Fishing Vessel Class, 2012-2019

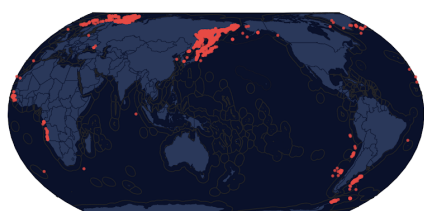
Drifting Longlines



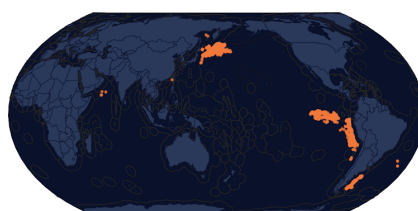
Tuna Purse Seines



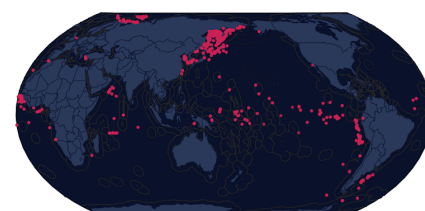
Trawlers



Light-Lure Fishing



Carrier Vessels



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Bunker vessels

The distribution of encounters with bunker vessels by gear type has a similar spatial pattern to encounters with carrier vessels, with a few notable differences (Figure 10). One difference is that vessels in the northwest Pacific ocean that use light-luring fishing methods generally encounter carrier vessels and less commonly meet bunker vessels (Figure 10, *light-lure fishing*). The reason for this pattern is unclear, but it does suggest that the network of support for these vessels is different from light-luring vessels in other regions.

We also see that purse seine vessels targeting tuna have a greater number of encounters with bunkers than they do carriers. These encounters occur predominantly within the EEZs of small island developing states, especially those that are Parties to the Nauru Agreement (PNA), although there is also a pocket of purse seine bunkering activity within the Gulf of Guinea (Figure 10, *tuna purse seines*). Operations with the PNA may, in part, be a manifestation of fisheries management regulations, which restrict the ability of purse seine operators to fish within specific high seas areas in return for the rights to fish within the tuna-rich waters of PNA members (Third Arrangement of the Nauru Agreement). Thus, purse seiners operating within these EEZs may simply bunker in the same locations that they fish. It is also possible that fishing vessels operating in some regions can simply avoid a potential price markup on fuel bought in port by bunkering at sea. Encounters are likely missing from the Indian Ocean because many of the tuna purse seiners that operate in this region disable their AIS (Nieblas et al., 2019).

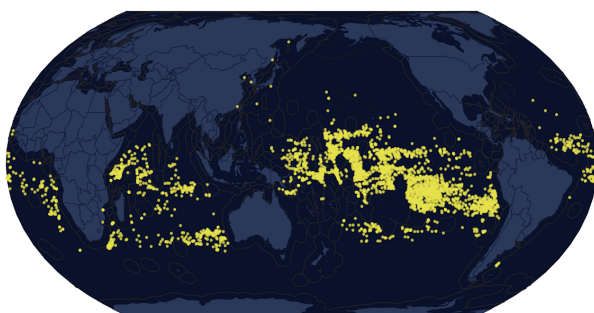
Bunker vessels also encounter carrier vessels in an equatorial band in the Pacific Ocean, as well as near Peru and Argentina and along the west coast of Africa (Figure 10, *carrier vessels*). These activities are of some interest, as both carriers and bunker vessels can refuel fishing vessels at sea; hence, carrier vessels may be obtaining fuel for their own use or for reselling.

To the extent that bunker vessel encounters within EEZs represent refueling of foreign-flagged vessels, they are of considerable interest. The UN Convention on the Law of the Seas (UNCLOS) provides coastal States the right to regulate bunkering of foreign fishing vessels within their EEZ (UNCLOS, Article 56(1)a). However, in practice, monitoring such activity may prove difficult if the bunker vessel is not visible in a national tracking system (such as in national vessel monitoring systems).

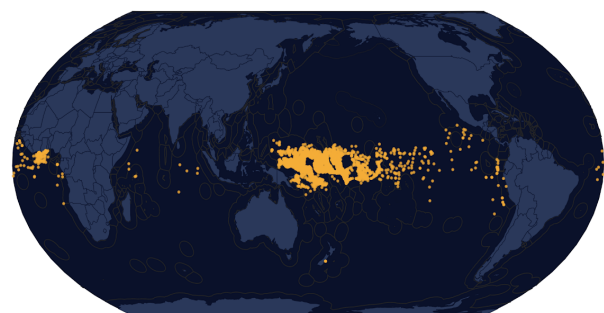
Figure 10

Bunker Vessel Encounters by Fishing Vessel Class, 2012-2019

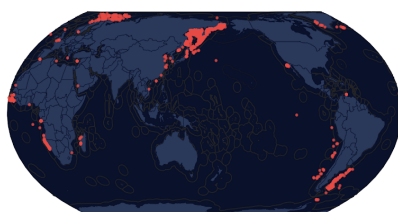
Drifting Longlines



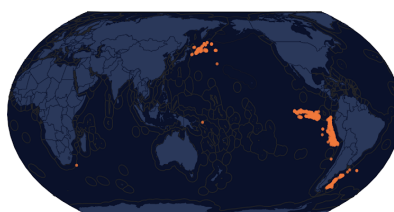
Tuna Purse Seines



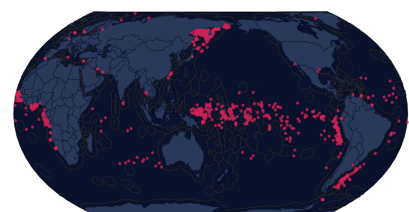
Trawlers



Light-lure Fishing



Carrier Vessels



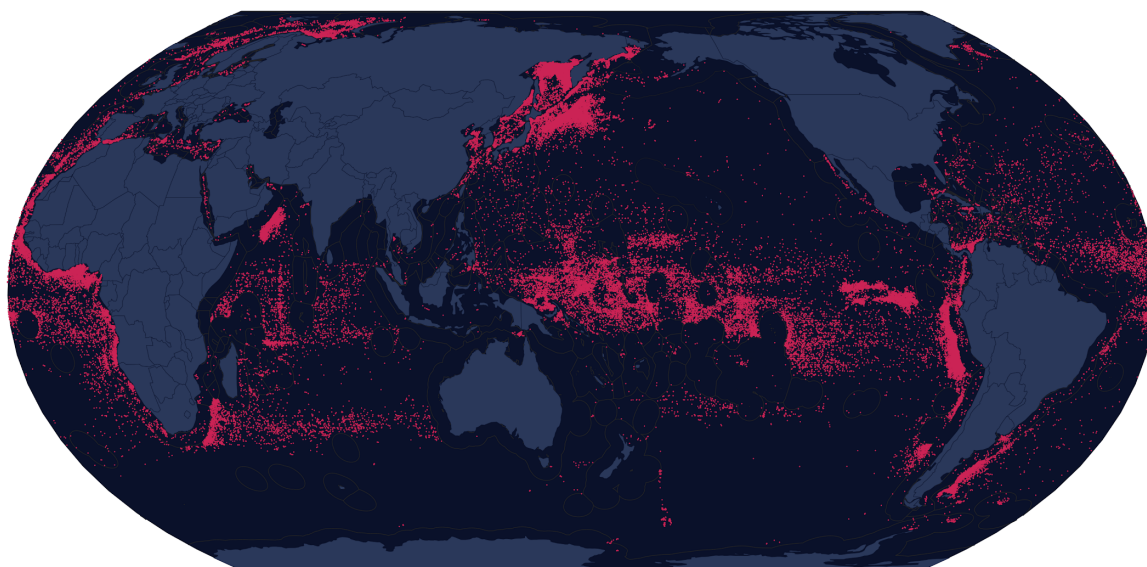
Comparing the spatial footprint of carrier vessel loitering activity (Figure 11) to the footprint of encounters (Figure 8) can help identify areas where fishing vessels are likely operating and engaging in transshipment without AIS.

Spatial footprint of support: Loitering and estimating the non-broadcasting fleet

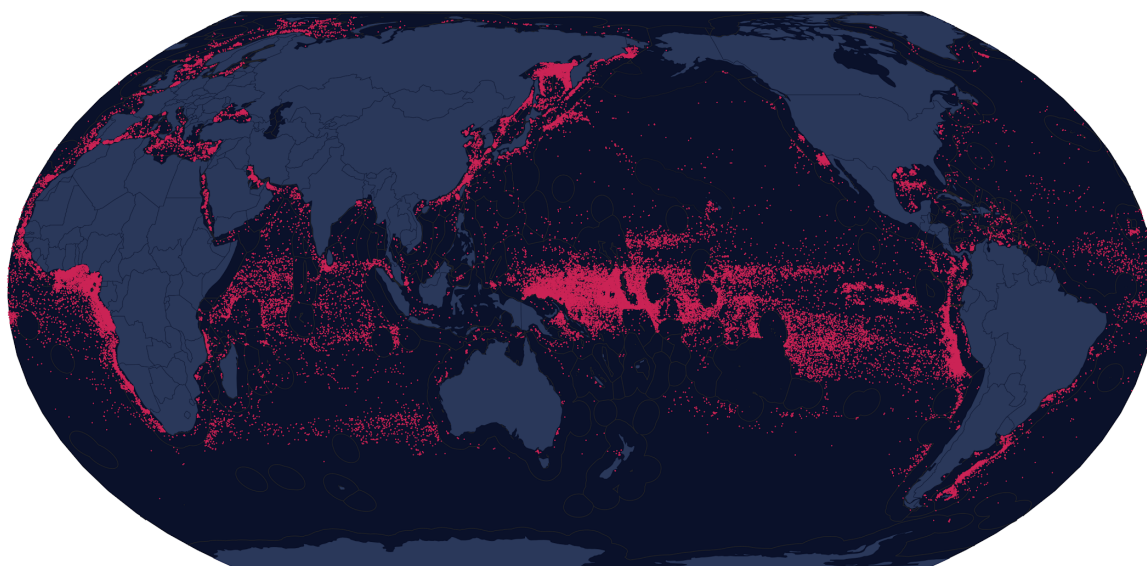
Figure 11

Carrier and Bunker Vessel Loitering Events, 2012-2019

Carrier Vessels



Bunker Vessels



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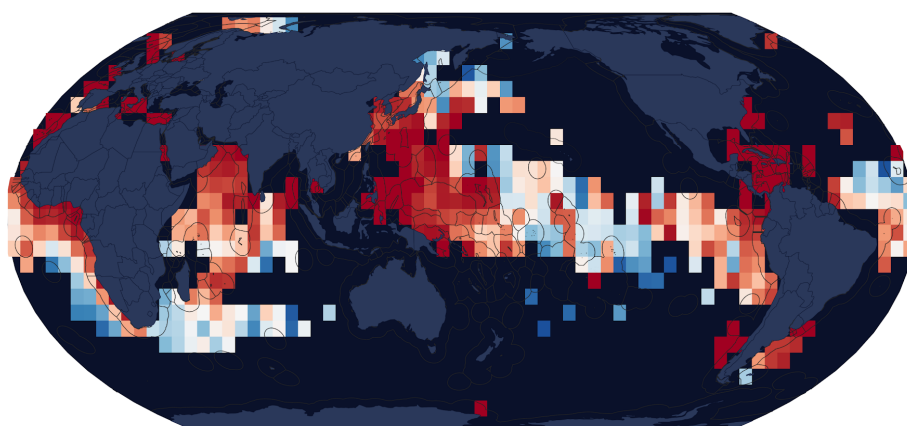
If we assume each carrier loitering event represents an encounter with an unseen vessel, we can use the fraction of loitering events unmatched to encounters to estimate regions where fishing vessels may be operating without AIS. This assumption may not be valid in some regions where loitering events by carrier vessels do not represent transshipment (such as waiting to enter port, etc.). However, if as a first approximation, we divide the number of carrier loitering events

unmatched to encounters by the total number of carrier loitering events, some clear patterns emerge (Figure 12). In the southern Indian Ocean, central equatorial Pacific, central equatorial Atlantic and in Russian waters, the proportion of unmatched events is relatively low, suggesting that the majority of fishing vessels that engage in transshipment are broadcasting on AIS. The proportion is higher in Africa’s coastal waters, as well as those closer to South America, which may be explained by fewer vessels broadcasting their locations. In the far western Pacific, and in the far northern Indian ocean, the low proportion may be explained by poor AIS reception (See Figure S1).

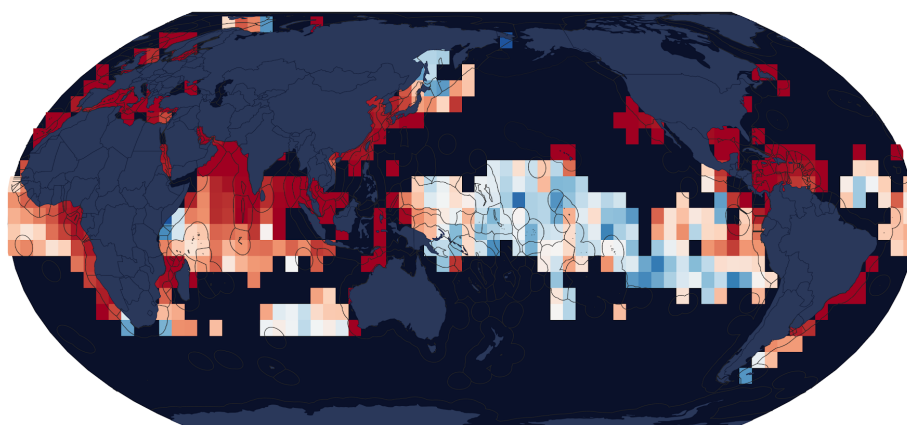
Figure 12

Fraction of Transshipment Behavior with Dark Vessels

Carrier Vessels



Bunker Vessels



Fraction of Loitering Unmatched to Encounters 0.00 0.25 0.50 0.75 1.00

The graphics above show a fraction of loitering events unmatched to encounters. If each loitering event represents an encounter, there should be an equal number of events in regions where AIS reception and AIS use by fishing vessels are high. Under similar conditions, in areas of low AIS reception or limited AIS use, we expect fewer encounters than loitering events. Blue grid cells represent regions where most loitering events can be matched to an encounter. Red grid cells represent regions where there are many more loitering events than encounters. Red areas may represent areas of low reception, low AIS use by fishing vessels, or areas in which vessels intentionally turn off their AIS devices.

Quantifying Ports of Support



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Aerial view of the Port of Busan in the Republic of Korea.

Carrier vessel port visits

Effective monitoring of fishing ports is important to combating IUU fishing and eliminating labor abuses on board fishing vessels, as it prevents illicit vessels' access to support and supply chains (Hosch et al., 2019). The [PSMA](#), which entered into force in 2016, requires parties to the agreement to place stricter port controls on foreign-flagged vessels linked to IUU fishing that are seeking to enter and use their ports. A cost-effective way to help curb illegal fishing, the agreement also calls on all parties to notify the flag State and other relevant stakeholders when a suspicious vessel requests port entry. Unscrupulous actors may seek to avoid scrutiny and operate out of ports with little or reduced oversight (so-called ports of noncompliance) or by steering clear of ports altogether through use of at-sea transshipment and bunkering. Given their role in supporting fishing activities, both carrier and bunker vessels, which often fly foreign flags and operate globally through a diverse set of ports, are covered under the PSMA.

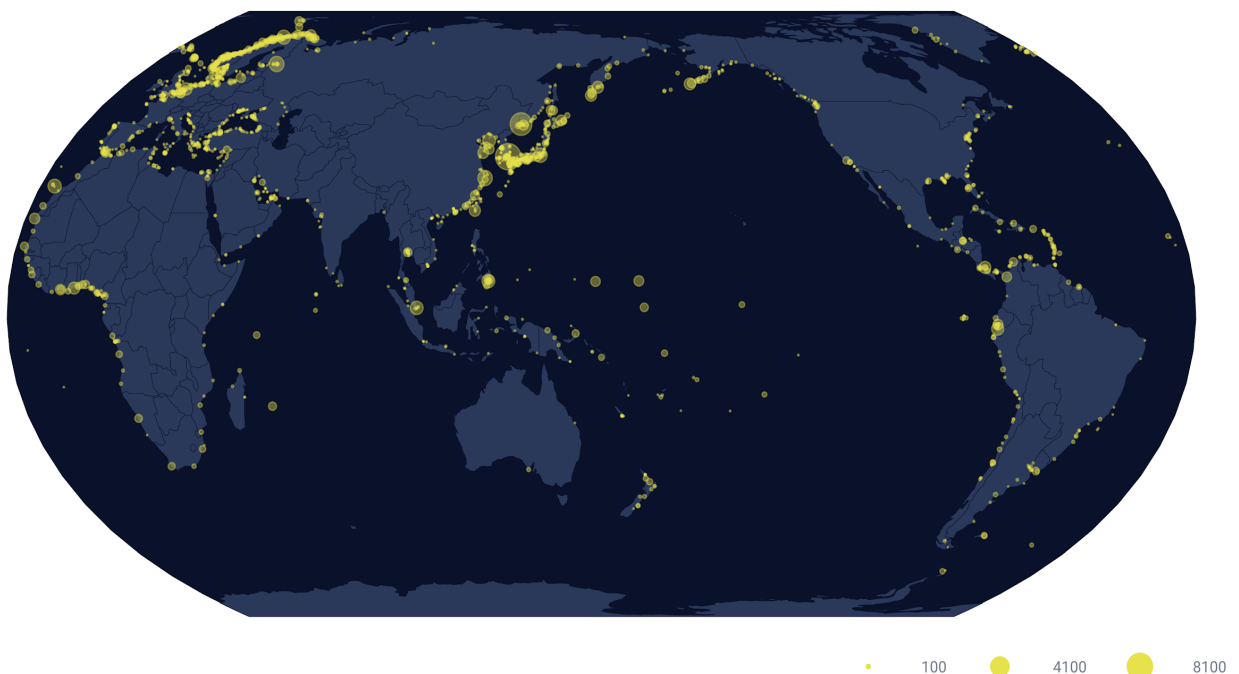
Our analysis details the most common ports visited by all carrier and bunker vessels, as well as those ports that were visited following at least one encounter with a fishing vessel. But there are several caveats to the results. First, transshipment vessels may visit many additional ports—these are simply those ports they appear to visit after a voyage during which encounters were identified. In other words, these ports represent the first stop that each transshipment vessel made after a voyage but not necessarily the location where catch was landed. We have omitted intermediate port stops of less than three hours to avoid very brief port stops, but catch may still have been offloaded at an intermediate stop.

Ports used by all carriers

From 2012-2019 carrier vessels within the Global Fishing Watch dataset visited 228 different ports in 80 countries, illustrating the truly global footprint of their operations (Figure 13). For comparison, we documented the top ports visited by all carriers in Table 1. The ports were ranked in relative importance using two metrics: the total number of carrier vessel visits and the total number of unique carrier vessel visits. The first metric identifies ports that are visited frequently, while the second identifies ports that are used by many different carriers. When it comes to carrier vessels' port visits, both metrics rank Busan (Republic of Korea), Zhoushan (China) and Saint Petersburg (Russia) relatively high. Vladivostok (Russia) had a significant number of total carrier visits, but represented only 212 unique vessels, while Singapore (Singapore) had fewer total visits but a more diverse set of carrier vessels.

Figure 13

Geographic Location of Ports Visited by Carrier Vessels, 2012-2019



Note: Symbol area represents the total number of visits by carriers, with larger symbols representing more visits.

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Table 1

Ports Ranked by Total Carrier Vessel Visits and Total Number of Unique Carrier Vessel Visits, 2012-2019

<i>Port</i>	<i>Total carrier visits</i>	<i>Port</i>	<i>Unique carrier visits</i>
Busan, Republic of Korea	8,128	Busan, Republic of Korea	472
Vladivostok, Russia	5,880	Singapore, Singapore	359
St. Petersburg, Russia	2,503	Zhoushan, China	286
Zhoushan, China	2,302	Las Palmas, Spain	246
Yokosuka, Japan	2,126	Dalian, China	227
Tromso, Norway	2,107	St. Petersburg, Russia	216
Los Palmas, Spain	2,011	Vladivostok, Russia	212
Davao, Philippines	1,898	Qingdao, China	193
Singapore, Singapore	1,859	Weihai, China	199
Dalian, China	1,838	Tema, Ghana	190

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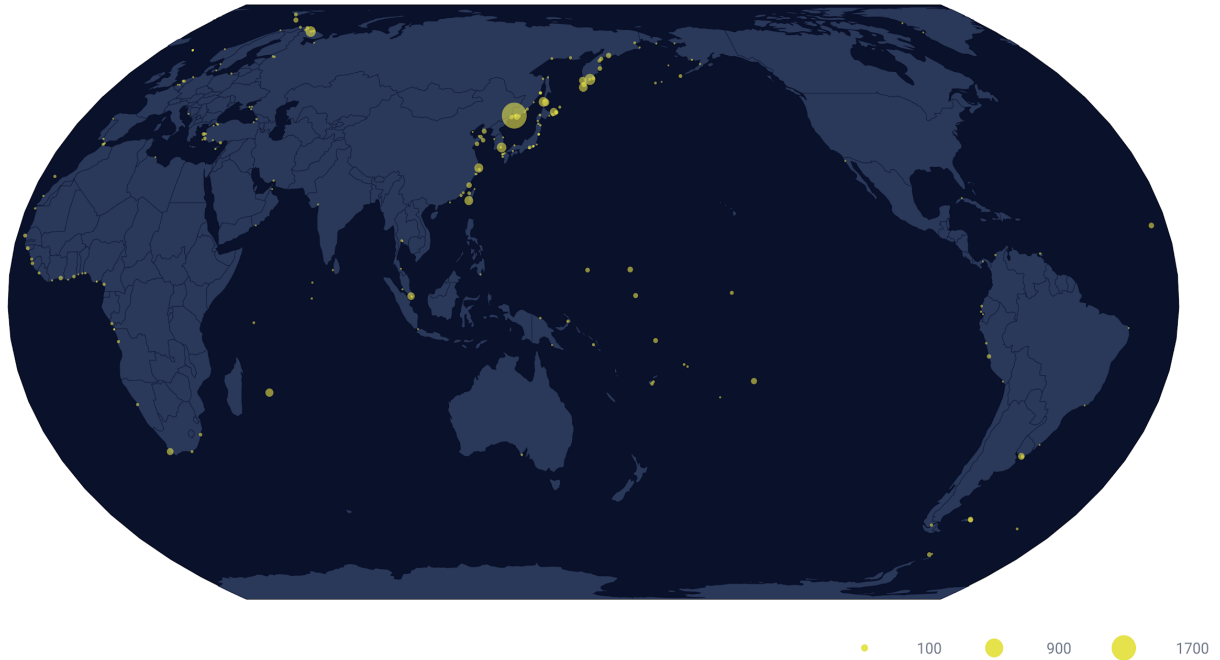
Ports visited following encounters

We have previously shown that roughly 15-20 percent of all carriers in the dataset do not exhibit transshipment-like behavior and with the longer-term goal of linking catch to port, we restricted the subsequent analysis to ports visited by carriers that had at least one encounter with a fishing vessel on each voyage (Figure 14, Table 2). Large ports in Russia, Republic of Korea, China, Chinese Taipei and Mauritius predominate. Given the prevalence of encounters in the Russian EEZ and the requirement for vessels carrying fish caught within the Russian EEZ to stop in a Russian port prior to visiting a foreign port, the number of visits to Russian ports is not unexpected (WWF, 2019).

To identify the potential amount of transshipped catch that might be associated with each port, we identified fishing activity before an encounter with a carrier vessel, including all fishing activity up to three weeks before or between the encounter and the previous port visit or encounter, whichever period was shorter. We then identified the first port stop for each carrier. The following ports accounted for over 50 percent of the potentially transshipment fishing effort: Vladivostok (Russia), Zhoushan (China), Port Louis (Mauritius), Kaohsiung (Chinese Taipei) and Busan (Republic of Korea). And 90 percent of the potentially transshipped effort entered just 30 ports. These ports represent the first stop following a voyage, and these vessels may or may not have offloaded fish at these ports. However, these findings suggest that a significant portion of the fish that is transshipped at sea may pass through just a few ports.

Figure 14

Geographic Locations of Ports Visited by Carrier Vessels Following Encounters with Fishing Vessels, 2012-2019



Note: Symbol area represents the number of total visits by carriers, with larger symbols representing more visits.

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Table 2

Ports Ranked by Total Carrier Vessel Visits and Total Number of Unique Carrier Vessel Visits Following an Encounter with a Fishing Vessel, 2012-2019

<i>Port Name</i>	<i>Total Carrier Visits</i>	<i>Port Name</i>	<i>Unique Carrier Visits</i>
Vladivostok, Russia	1,791	Vladivostok, Russia	136
Petropavlovsk, Russia	282	Busan, Republic of Korea	96
Murmansk, Russia	252	Severo-Kuril'sk, Russia	77
Busan, Republic of Korea	215	Petropavlovsk, Russia	73
Nevelsk, Russia	206	Zhoushan, China	55
Zhoushan, China	183	Oktyabrskiy, Russia	54
Kaohsiung, Chinese Taipei	180	Singapore, Singapore	47
Severo-Kuril'sk, Russia	170	Port Louis, Mauritius	46
Port Louis, Mauritius	145	Kaohsiung, Chinese Taipei	43
Yuzhno-Kuril'sk, Russia	135	Korsakov, Russia	42
Singapore, Singapore	117	Yuzhno-Kuril'sk, Russia	39
Oktyabrskiy, Russia	112	Berkeley Sound, Falkland Islands (Malvinas)	37

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Foreign carrier port visits

If we focus on ports that are visited by foreign-flagged vessels following an encounter with a fishing vessel, the pattern switches away from Russian ports, which are most often visited by Russian-flagged vessels, and pivots to Busan (Republic of Korea), Port Louis (Mauritius), Zhoushan (China) and Singapore (Singapore). Approximately 43 percent of all visits by foreign-flagged carriers, following an encounter, involved States that were a party to the PSMA. These States have committed to eliminating IUU fishing by, at a minimum, inspecting foreign vessels and preventing vessels associated with IUU catch from entering any ports. Some of the clear outliers in Table 3 are China, Singapore, and the Pacific small island developing States. The Pacific, however, is not without port State controls, and while many members of the Pacific Islands Forum Fisheries Agency (FFA) have not ratified the PSMA (only Palau, Tonga and Vanuatu have), members of the WCPFC have implemented CMM 2017-02, an optional minimum standards for port State measures meant to combat IUU fishing. China has signaled that it may join the PSMA soon (Woody, 2019), a move that would increase carrier visits to PSMA States in our analysis to roughly 59 percent. While Russia

ratified the PSMA in December 2020, its ports are not as frequently visited by foreign carrier vessels and thus will not have as large an impact as a ratification by China.

Table 3

Top 20 Ports for Foreign-Flagged Carriers, 2012-2019

<i>Port Name</i>	<i>Total Carrier Visits</i>	<i>Port Name</i>	<i>Unique Carrier Visits</i>
Busan, Republic of Korea	176	Busan, Republic of Korea	88
Port Louis, Mauritius	145	Zhoushan, China	54
Zhoushan, China	138	Port Louis, Mauritius	46
Singapore, Singapore	110	Singapore, Singapore	46
Cape Town, South Africa	97	Berkeley Sound, Falkland Islands (Malvinas)	37
Montevideo, Uruguay	90	Montevideo, Uruguay	35
Papeete, French Polynesia	73	Kaohsiung, Chinese Taipei	34
Kaohsiung, Chinese Taipei	69	Fuzhou, China	30
Majuro, Marshall Islands	59	Funafuti, Tuvalu	28
Berkeley Sound, Falkland Islands (Malvinas)	58	Dalian, China	27
Porto Grande, Cabo Verde	56	Cape Town, South Africa	25
Fuzhou, China	45	Callao, Peru	23
Bjornoya, Svalbard and Jan Mayen	43	Qingdao, China	23
Funafuti, Tuvalu	40	Tarawa, Kiribati	22
Tarawa, Kiribati	40	Papeete, French Polynesia	20
Dalian, China	37	Pohnpei, Micronesia	20
Pohnpei, Micronesia	35	Stanley, Falkland Islands (Malvinas)	20
Stanley, Falkland Islands (Malvinas)	34	Majuro, Marshall Islands	19
Qingdao, China	31	Abidjan, Côte d'Ivoire	18
Abidjan, Côte d'Ivoire	29	Porto Grande, Cabo Verde	18
Callao, Peru	29		

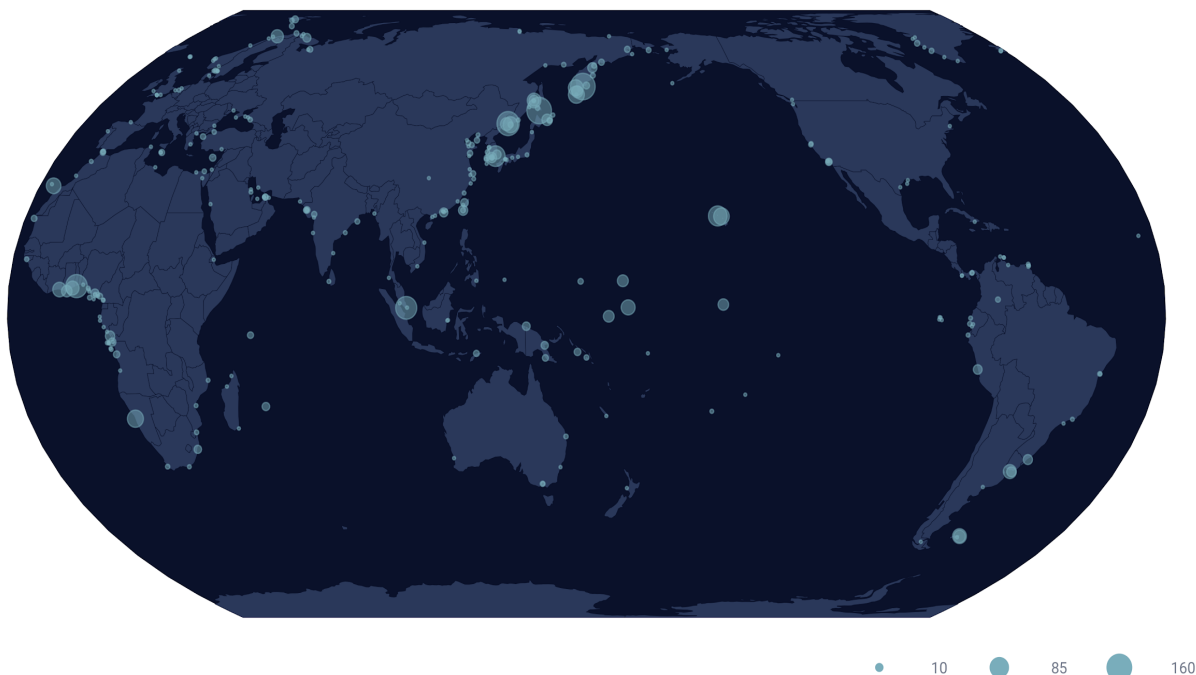
Note: States highlighted above have ratified or acceded to the Port State Measures Agreement as of January 2021.

Bunker vessels port visits

Though they are not consistently listed in RFMO registries, bunker vessels that supply fishing vessels are included under PSMA (PSMA Article 1(d) and (j)) and should be subject to the same port restrictions and inspection regimes as foreign fishing vessels and fish carriers. We found that bunker vessels that frequently meet up with fishing vessels visit distinctly different ports than fishing or carrier vessels (Figure 15, Table 4). Many of these ports are located in the western region of Africa, which are known for oil and gas development, including Angola, Côte d'Ivoire, Ghana, Namibia, Republic of Congo and Togo. It is known that Namibia and Togo serve as hubs for the bunkering company [Monjasa](#), while [OMA Group Ltd](#) offers bunkering services in western Africa, and Minerva Bunkers and Oryx Bunkering Services operate in both eastern and western Africa (BunkerSpot). Some ports such as Las Palmas (Spain), Singapore (Singapore) and Busan (Republic of Korea) are recognized as important bunkering ports (Tradewinds), while others such as Kaohsiung (Taiwan), Honolulu (United States of America) and Montevideo (Uruguay) are frequented by carrier and bunker vessels.

Figure 15

Ports Visited by Bunker Vessels Following Encounters with Fishing Vessels, 2012-2019



Note: Symbol area represents the number of total visits by bunker vessels, with larger symbols representing more visits.

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Table 4

Top Ports for Bunker Vessels, 2012-2019

<i>Port</i>	<i>Bunker Visit Count</i>	<i>Port</i>	<i>Unique Bunker Visits</i>
Lome, Togo	394	Lome, Togo	59
Petropavlovsk, Russia	197	Singapore, Singapore	52
Korsakov, Russia	187	Vladivostok, Russia	43
Chaguaramas, Trinidad and Tobago	178	Nakhodka, Russia	38
Walvis Bay, Namibia	154	Busan, Republic of Korea	34
Singapore, Singapore	148	Las Palmas, Spain	26
Vladivostok, Russia	147	Petropavlovsk, Russia	26
Busan, Republic of Korea	127	Walvis Bay, Namibia	25
Pointe Noire, Congo	103	Tema, Ghana	24
Honolulu, United States of America	100	Abidjan, Côte d'Ivoire	22
		Pointe Noire, Congo	22
		Vanino, Russia	22

Ports visited by bunker vessels following voyages during which at least one encounter with a fishing vessel took place. Ports are ranked by the total number of visits by bunker vessels and the total number of unique bunker vessels that visited a port. The patterns shift over time with very few visits detected in 2012. The top ports remain relatively consistent over time, but the relative order may vary by year.

Note: States highlighted above have ratified or acceded to the Port State Measures Agreement as of January 2021.

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Networks supporting labor rights risk on drifting longliners

In recent years, there has been a growing awareness of the prevalence of forced labor within the fishing sector. The International Labor Organization (ILO) defines forced labor as “all work or service which is exacted from any person under the menace of any penalty and for which the said person has not offered himself voluntarily.” The issue of forced labor in fisheries has received considerable media coverage, especially regarding the role of slavery in seafood imported by major market states. Despite recognition of the practice, however, there has been no means of identifying the risk of forced labor at an individual vessel level. This all changed when researchers at the University of

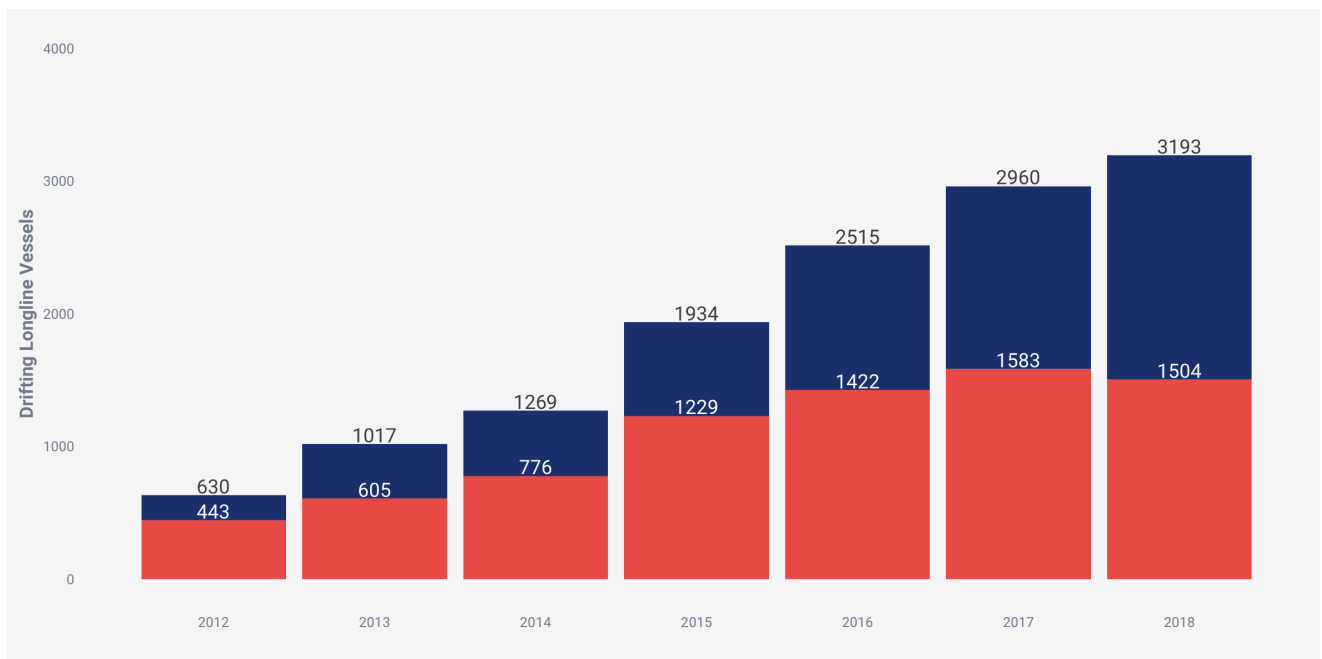
California, Santa Barbara (UCSB), working with Global Fishing Watch and other partners, revealed that vessels using forced labor behave in systematically different ways from other vessels. These researchers developed a machine learning model that uses these systematic differences in behavior to identify vessels at greater risk of using forced labor. Here we will refer to those vessels identified as being at higher risk of forced labor as “more risky” or “higher-risk” vessels and those not identified by the model as “less risky” or “lower-risk” (McDonald et al., 2020).

We have applied the output of the UCSB model—drifting longline vessels identified as being at greater and lesser risk of using forced labor—to identify those carrier and bunker vessels that support these fishing vessels, as well as the ports these support vessels frequent. We have focused specifically on longline vessels, as they appear to have the highest fraction of labor violations and have low observer coverage compared to some other vessel classes. Drifting longliners account for over 11 percent of the global tuna landings and a significant amount of the albacore tuna catch (72 percent in 2018, equivalent to 144,000 metric tons) often destined for cans and pouches along with 69 percent (13,800 metric tons in 2018) of the southern bluefin tuna (Pew, 2020). The number of high seas drifting longline vessels that are active and trackable using AIS has increased since 2012 and a fraction of those considered risky has decreased from 70 percent to 47 percent, with the absolute number of higher-risk vessels peaking in 2017 (Figure 16).

Higher-risk drifting longliners

Figure 16

Drifting Longline Vessels and Risk of Using Forced Labor



Note: Higher-risk vessels shown are in red and lower-risk vessels are shown in blue.

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Carrier and bunker vessel encounters with longline vessels

According to the UCSB risk model, almost all drifting longliners that meet up with carrier vessels have an elevated risk of forced labor. Of the 905 drifting longliners that met up with carrier vessels,

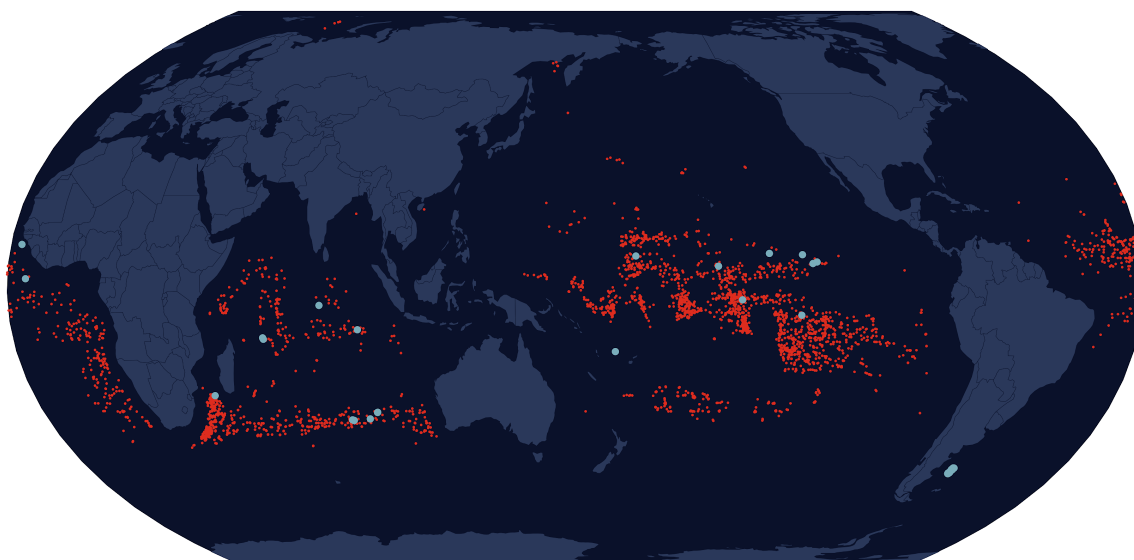
all but 73 had a high risk of forced labor, roughly 8 percent. Interestingly, the 8 percent of lower-risk longliners had more encounters per vessel. As a result, about 88 percent (3,113 vessels) of all encounters between drifting longliners and transshipment vessels from 2012 and 2018 involved a higher-risk drifting longline vessel (Figure 17). Notably, over half of the higher-risk longliners had no identified encounters, suggesting that either not all high-risk vessels transship or that these vessels often do not broadcast on AIS while transshipping.

These findings should be viewed with some caution, as this model was trained on only 14 higher-risk longline vessels. Additionally, even among these vessels, there was uncertainty in when forced labor was actually used, leading to additional uncertainty in model results.

The findings suggest that a significant proportion of the carrier voyages between 2012 and 2018, and the fish carried during those voyages, are at risk of being associated with forced labor. The total number of carrier voyages that involve an encounter with a higher-risk longline vessel has generally increased each year (Figure 18). This increasing number of higher-risk carrier voyages may be related to the increasing numbers of higher-risk longline vessels (Figure 16). It may also be explained in part by improved ability to detect vessel encounters as more AIS-detecting satellites have launched, which allows more vessel positions to be detected each day.

Figure 17

Location of Encounters between Higher-Risk Drifting Longliners and Carrier Vessels

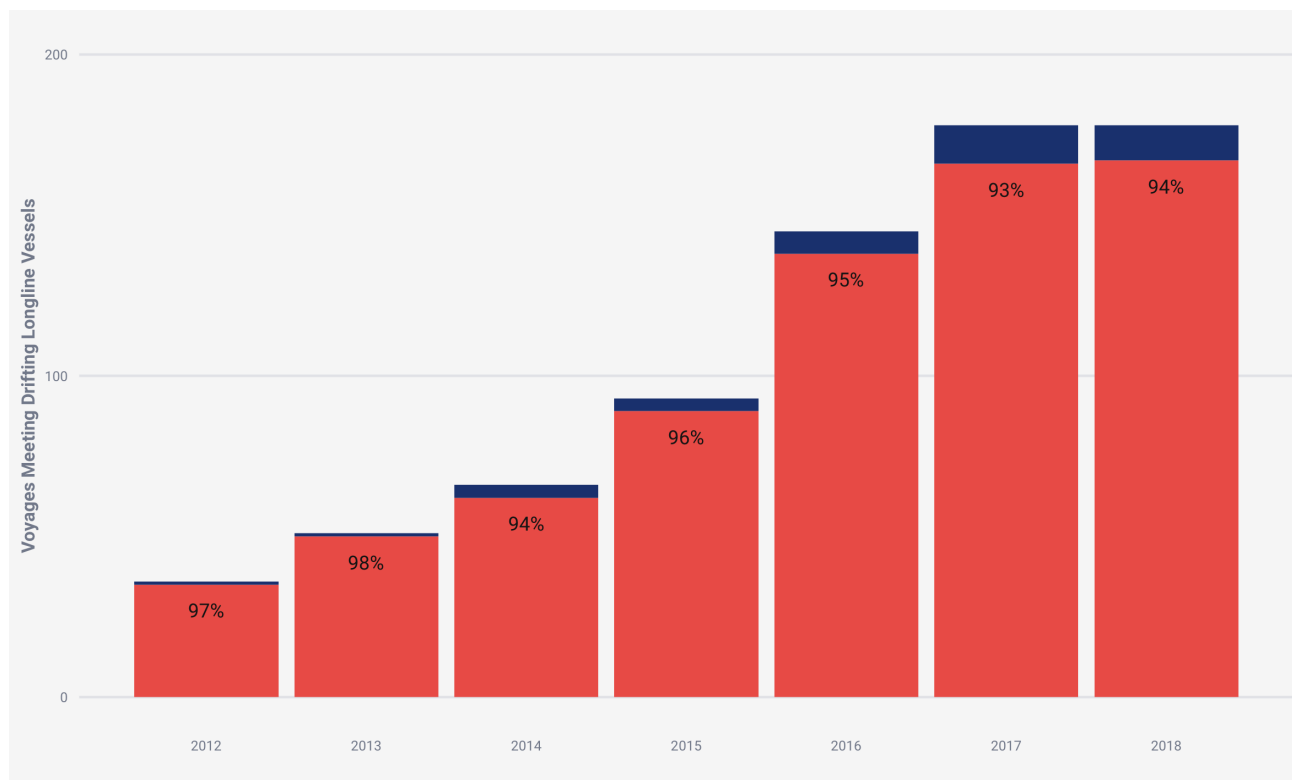


Note: Encounters with higher-risk vessels are shown in red, and encounters with lower risk vessels are shown in blue. The point size of the encounters involving lower-risk longliners have been enlarged to make them easier to view.

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Figure 18

Number of Carrier Voyages Involving Encounters with Higher-Risk Drifting Longline Vessels



The fraction of the total voyages that involve a higher-risk vessel declines very slightly after 2016 as the number of total voyages increases, though the total number of carrier voyages that involve a higher-risk vessel remains high.

Note: Higher-risk voyages are shown in red and lower-risk voyages (no encounters with a higher-risk vessel) are shown in blue.

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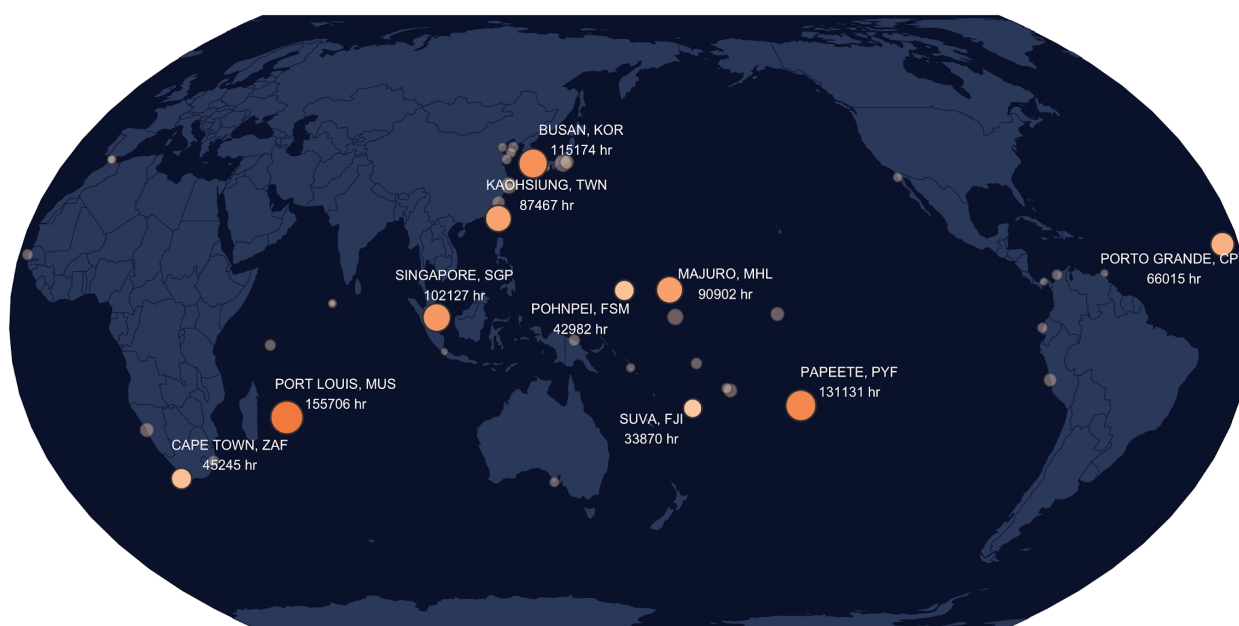
Ports supporting high-risk transshipment

Approximately 95 percent of the 664 carrier voyages that involved at least one encounter with a drifting longline included an encounter with a risky drifting longline. To determine the potential amount of catch that was associated with each encounter, we used an approach outlined previously, identifying fishing activity before an encounter with a carrier vessel, including all fishing activity up to three weeks before or between the encounter and the previous port visit or encounter—whichever period was shorter. We then identified the most common first port stops for carriers after having encountered a higher-risk longline vessel (Figure 19). The following ports were identified as top destinations after ranking each by the total fishing hours potentially associated with forced labor: Port Louis (Mauritius), Papeete (French Polynesia), Busan (Republic of Korea), Singapore (Singapore), Majuro (Marshall Islands), Kaohsiung (Chinese Taipei), Porto Grande (Cabo Verde), Cape Town (South Africa), Pohnpei (Federated States of Micronesia) and Suva (Fiji). These ports represent the first stop following the voyage. While these vessels may or may not have offloaded fish at these ports, the locations represent nodes in the network at which regulation and enforcement could be applied. The [ILO Work in Fishing Convention](#) (C188), which entered into force

in 2017, requires States that are a party to the convention to inspect foreign-flagged fishing vessels “engaged in commercial fishing operations”. Although carrier and bunker vessels are not directly involved in commercial fishing operations—they participate in fishing related activities—C188 allows States to determine whether it is necessary to apply provisions to a given vessel. To date, South Africa is the only party to C188 identified as having a frequently-visited port potentially associated with forced labor. Additional measures include requiring vessel operators to report where the fish was caught, by whom and under what authorizations, as there is evidence to suggest [links](#) between the use of forced labor in fishing and the conduct of IUU fishing activity.

Figure 19

Common Destinations for Carrier Vessels Following Encounters with Higher-Risk Drifting Longline Vessels



Note: Marker size represents the total number of fishing hours logged by carrier vessels visiting that port (actual fishing hours provided in the annotation).

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Support network for risky drifting longline vessels

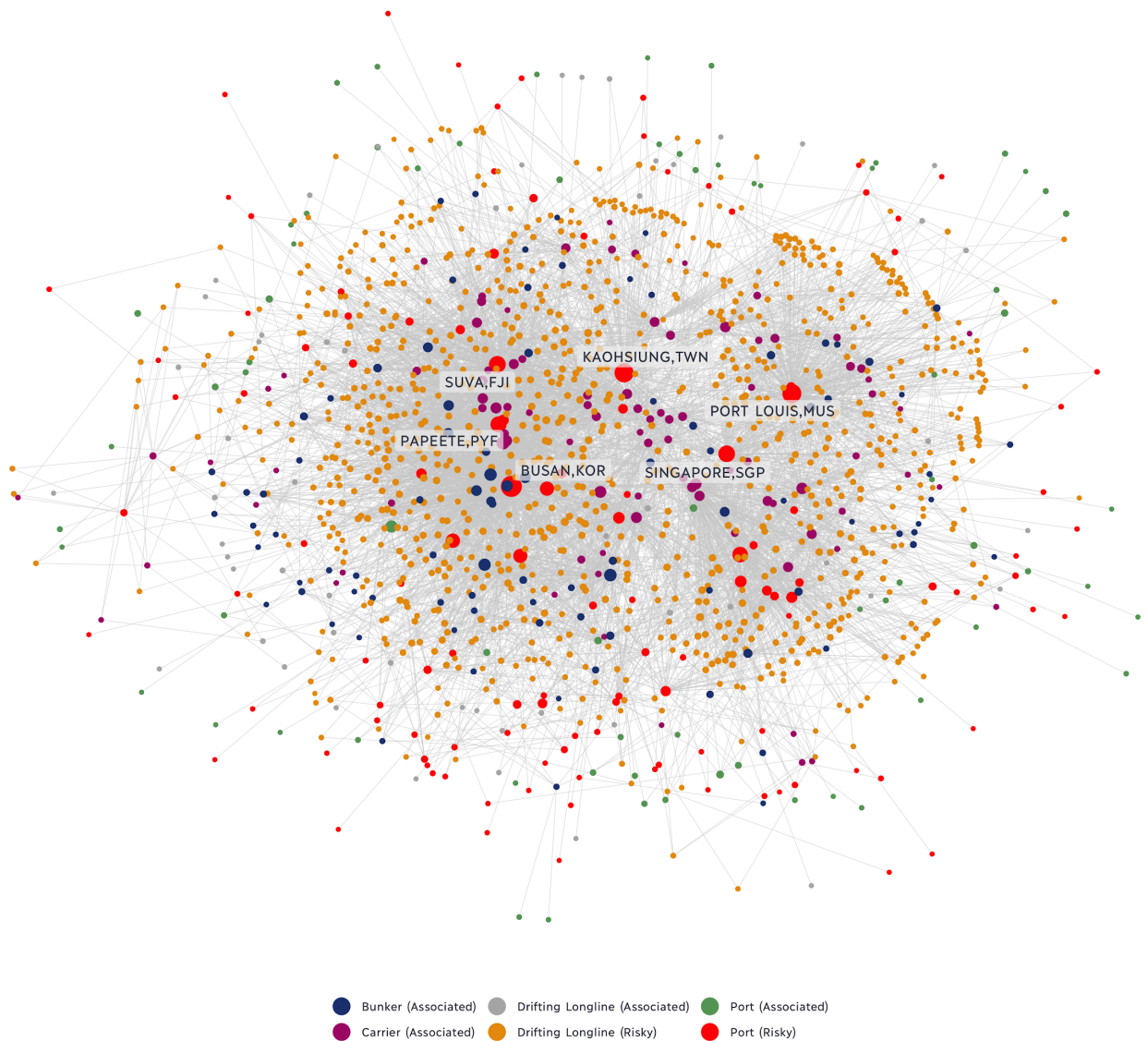
This report has presented a series of new and unprecedented datasets which promise to change our understanding of the entities that support the tuna supply chain, including:

- A database of carrier vessels
- A database of bunker vessels
- A database of at-sea encounters between carrier/bunker vessels and fishing vessels
- A database of loitering by carrier/bunker vessels
- A database of all ports frequented by these vessel classes

The strength of these datasets becomes apparent when they are combined to identify the network of support that enables high seas fishing operations. As an example, Figure 20 visualizes the network of support for longline vessels identified as at-risk of labor rights abuses, according to the

USCB risk model. This network identifies those carriers (purple) and bunkers (dark blue) that operate in conjunction with these higher-risk vessels (orange) supporting their operations. We can also identify those longline vessels that appear less risky (gray) but are associated with these higher-risk vessels through their interaction with the same support vessels. And finally we can identify those ports (red) that are directly connected to these higher-risk vessels (visited by the vessels themselves) as well as those ports that are associated with these higher-risk vessels (green). In this case, associated ports represent ports visited by support vessels that encountered riskier vessels. To simplify the model, nodes not associated with labor risk, either directly or through association, have not been included.

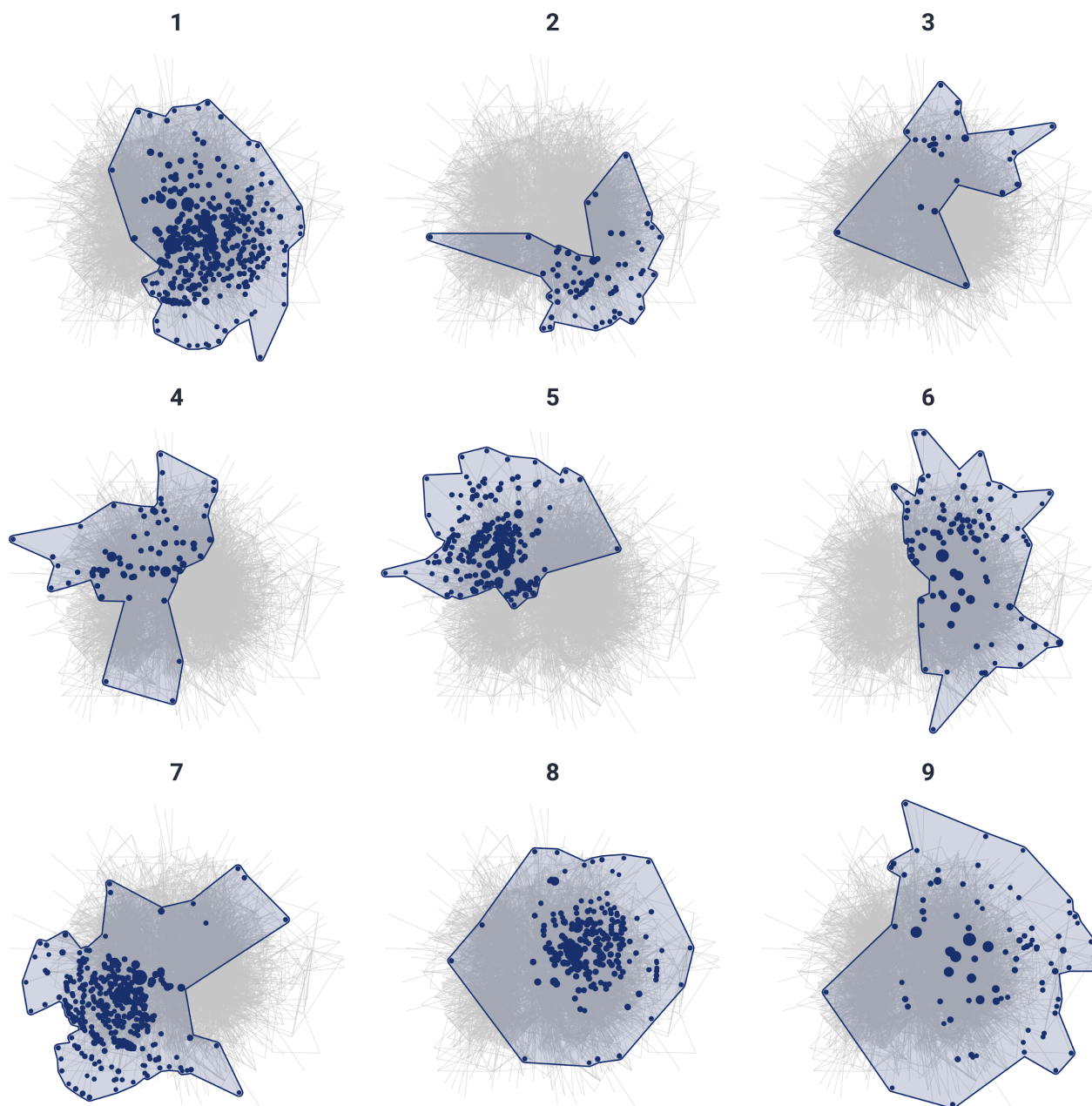
Figure 20
Network of Relationships Between Carrier, Bunker, and High-Risk Drifting Longline Vessels and the Ports they Visit.



Note: The five most frequently-visited ports by all vessels are annotated. The size of the nodes represents the number of connections, or node degree.

Figure 21

Communities Detected within the Carrier, Bunker, Drifting Longline Vessel and Port Network



Nine communities detected in the network supporting drifting longline vessels were at higher risk of using forced labor. Communities were detected using a multilevel community detection algorithm. Communities may include nodes representing longline vessels (both higher risk and lower risk) as well as carrier and bunker vessels, and the ports frequented by these vessels.

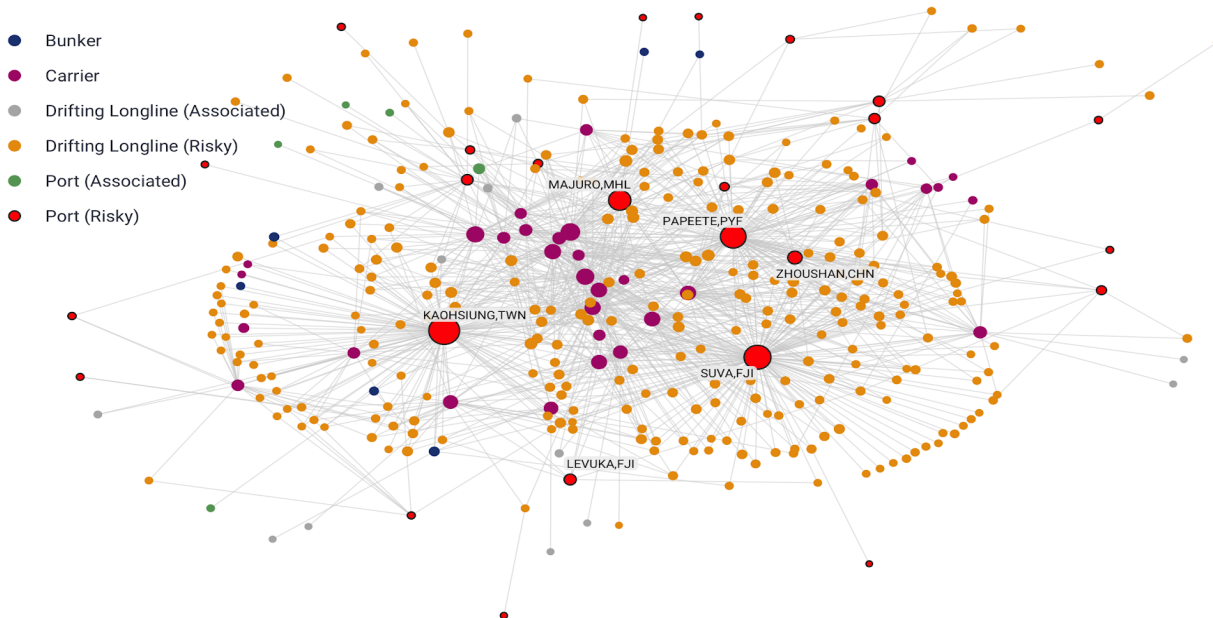
One strength of the network structure is that through it we can identify patterns of association and groups of vessels and ports that form statistically-identified “communities” (Park and Stamato, 2020). Figure 21 illustrates the result of the application of a multilevel community detection algorithm to the network shown in Figure 20, which has identified 9 distinct communities. Each community may include carriers, bunkers, longliners and ports. As the identity of nodes in each community is known, we can use the communities to identify previously hidden structures in the operations that support vessels most at risk of labor abuses.

For example, Community 1 identifies higher-risk drifting longline vessels that frequent ports in the Pacific including Papeete (French Polynesia) and Majuro (Marshall Islands) in addition to Kaohsiung (Chinese Taipei) and Zhoushan (China). These vessels are predominantly a mix of Chinese-flagged vessels, perhaps operating out of Papeete, and vessels from Chinese Taipei operating out of Kaohsiung. The two groups are linked most strongly by their use of a common set of carrier vessels flagged primarily to Panama and Vanuatu (Figure 22).

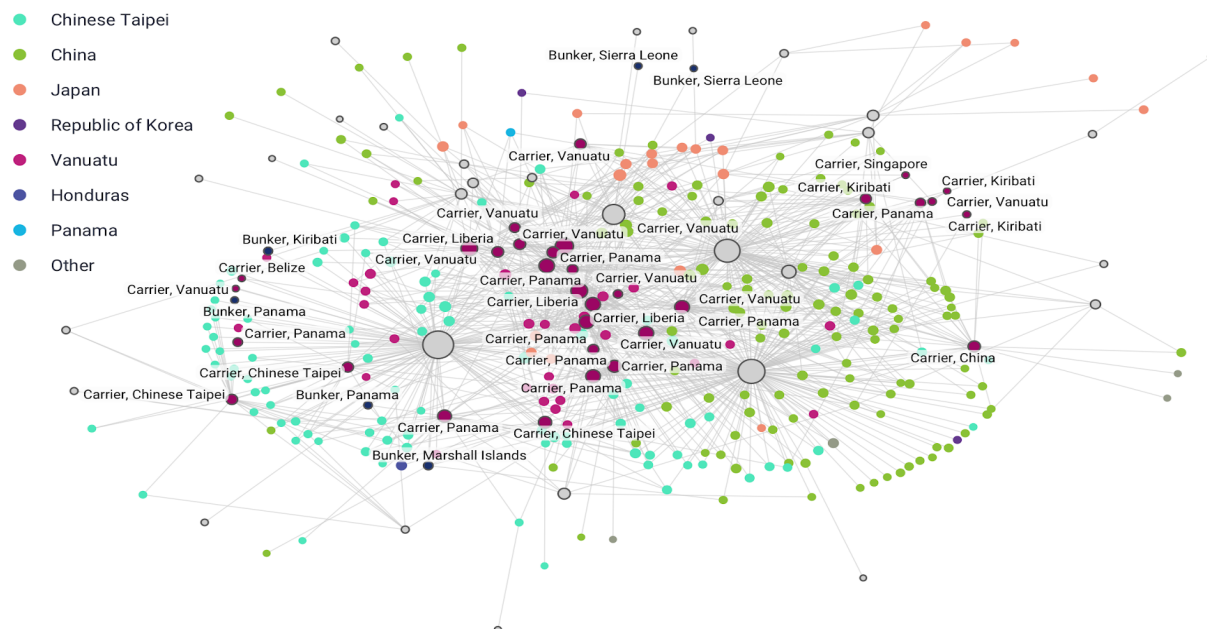
Figure 22

Vessels and Ports Supporting High-Risk Drifting Longliners: Community 1

By Node Class



By Vessel Flag State



Others: Liberia:3, Ecuador:2, French Polynesia:2, Marshall Islands:2, Sierra Leone:2, Albania:1, Belize:1, Chile:1, Equatorial Guinea:1, Malaysia:1, New Zealand:1, Peru:1, Philippines:1, Singapore:1, Tonga:1

Both longline vessels and ports are identified as being “risky” (either vessels identified as higher risk of forced labor or ports visited by higher-risk vessels) and “associated” (either vessels that encountered carrier/bunkers that encountered higher-risk vessels or ports that were frequented by these carriers/bunker vessels). The top 6 ports (by number of visits) within the community are labeled by name when grouped by node class while the top ports are left as gray nodes with black outlines when grouped by flag State.

This community can be contrasted with Community 5, which features a set of Japanese-flagged longline vessels at greater risk of using forced labor frequenting ports in western Africa, along with a smaller set of vessels flagged to China and Chinese Taipei. A set of Japanese-, Liberian-, and Vanuatu-flagged carriers appear to be supporting riskier vessels and frequenting the same ports. The fleet is also supported by a set of bunker vessels flagged to Marshall Islands, Panama, and Liberia among others (Figure 23).

“According to the UCSB risk model, almost all drifting longliners that meet up with carrier vessels have an elevated risk of forced labor. Of the 905 drifting longliners that met up with carrier vessels, all but 73 had a high risk of forced labor, roughly 8 percent.”

We can also use the network structure to identify those nodes, whether they are specific ports, carrier vessels, or bunkers, that have the greatest “importance”—that is, the nodes that have the most connections—and serve as critical links in the network or whose removal leads to the greatest change in the network. In this way we can identify those points of greatest leverage, where the appropriate application of regulatory, management or enforcement efforts can have the greatest positive impact.

An active area of research is to identify the most important nodes for further investigation. The community detection analysis shown here should be viewed as a proof-of-concept, demonstrating that this type of network analysis can identify useful patterns of association, rather than a definitive result. The multilevel clustering algorithm incorporates a random component, and identifying stable communities requires repeated application of the algorithm. Furthermore, the multilevel algorithm is only one of many community detection algorithms that could be applied, each with different strengths, though care was taken in its selection here (Yang et al., 2016). Additional communities are visualized in the Supplemental Materials.

Conclusion

Global long-distance fleets generate millions of tons of fish that are served around the world each day, playing an important role in the economy of many nations. The fleets that transship at sea and rely on bunker vessels, however, have come under scrutiny as a potential source of illegal, unreported and unregulated activity (FAO report). Because of this risk, nearly every RFMO has numerous regulations on transshipment and requires significant documentation for every event (FAO report). But despite these regulations, there are many loopholes and unclear jurisdictions, often creating ambiguity around what is legal and what is not.

An example of this ambiguity is shown by a series of analyses on transshipment that Global Fishing Watch has conducted for each of the major tuna RFMOs, reviewing the authorizations of fishing vessels ([Tuna RFMO Transshipment Analysis](#)). In every RFMO, Global Fishing Watch has found a number of encounters between fishing and carrier vessels where one or both are not authorized to fish or transship, according to public records. Following conversations with the RFMOs, many of these apparently-unauthorized events were actually permitted. This discrepancy existed because the public records were in need of correction or the information required to determine authorization was not publicly available, leaving no opportunity for independent verification. The result is that because of this unclear information, even though many regulatory bodies and the United Nations argue for better transshipment monitoring, it is very difficult to provide a clear understanding of which transshipment activities are compliant with regulations and which are not.

Recent studies revealing the high risk of forced labor further emphasizes the need for transparency in distant water fishing fleet activities. Publication of vessel identification, authorization and tracking data of carrier and bunker vessels would encourage all stakeholders to use transparency to better implement policies to address IUU fishing and forced labor in fisheries, including regional regulations on transshipment, the PSMA and C188. To support increased transparency, Global Fishing Watch is publishing all the associated data with this report at globalfishingwatch.org.

We are also working with management and enforcement bodies to provide information on vessels and regions of high risk. Because the dataset on forced labor is still in development, and since we do not want to unfairly identify specific vessels as having forced labor, we are not publicly sharing the risk scores of individual vessels, but we are actively working to improve the information and

hope to share it in the near future. Nonetheless, the datasets and analyses presented in this report here can hopefully serve as a step towards the improved management of long-distance fishing fleets.

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Supplemental Materials

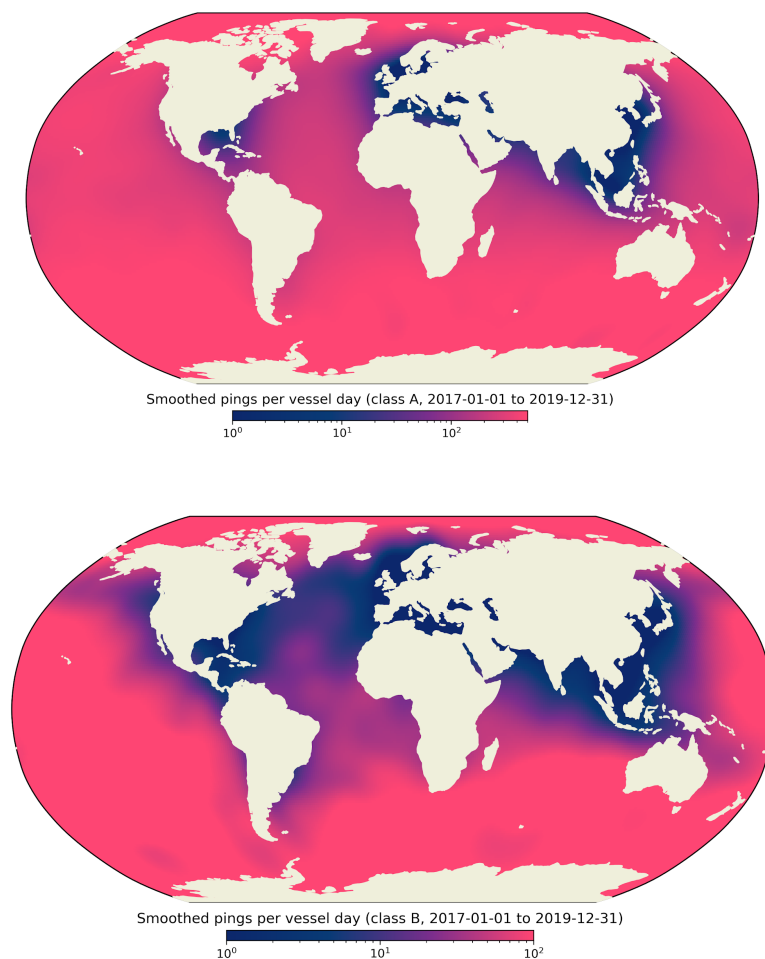
AIS reception

There are generally three “classes” of AIS devices: Class A, Class B, and Class B+. Devices offering stronger, more frequent and more consistent AIS transmissions are classified as Class A. They result in greater AIS reception for vessels in general (especially by satellites), as well as in regions of higher vessel density, where several AIS transmissions may occur simultaneously and cancel each other out (Figure S1). Class A reception is fairly good in most parts of the world except near East and South Asia, Europe and the southeast United States.

Class B reception is poor across the entire northern Atlantic, and in much of the northern Indian Ocean and far western Pacific Ocean. Many drifting longline vessels, especially those from Chinese Taipei and China, use Class B devices. They transmit at lower frequency and at lower strength, making it more difficult to track their transshipment activities in areas with poor satellite reception.

Figure S1

Global AIS Reception by Transmitter Type



Smoothed satellite reception quality in units of AIS positions (“pings”) per vessel day for Class A AIS (top) and Class B AIS (bottom) during 2017-2019. The Global Fishing Watch dataset draws on data from Orbcomm and Spire satellite providers.

Identification of bunker and transshipment vessels

Vessels classified as “refrigerated cargo” vessels, “fish carriers,” and “fish tender” vessels—vessels we collectively refer to as “transshipment vessels”—or those classified as “bunker” vessels were identified using lists from the International Telecommunications Union, major regional fisheries management organizations and other national registries (see Table S1).

Table S1

Vessel registry data sources used to develop list of transshipment vessels

Registry Source Name	Access
International Telecommunications Union (ITU) Registry	https://www.itu.int/pub/R
International Maritime Organization Global Integrated Shipping Information System (IMO GISIS)	https://gisis.imo.org
Western and Central Pacific Fisheries Commission (WCPFC) Authorized Vessel Registry	https://www.wcpfc.int/record-fishing-vessel-database
Consolidated List of Authorized Vessels (CLAV) Registry	http://www.tuna-org.org/GlobalTVR.htm
International Commission for the Conservation of Atlantic Tunas (ICCAT)	https://www.iccat.int/en/vesselsrecord.asp
Indian Ocean Tuna Commission (IOTC) Registry of Authorized Vessels	http://www.iotc.org/vessels/date
Inter American Tropical Tuna Commission (IATTC) Register of Authorized Vessels	https://www.iattc.org/VesselRegister/VesselList.aspx?List=RegVessels&Lang=ENG
Commission for the Conservation of Southern Bluefin Tuna (CCSBT) Record of Authorized Vessels	https://www.ccsbt.org/en/content/ccsbt-record-authorised-vessels
South Pacific Regional Fisheries Management Organization (SPRFMO) Record of Authorized	https://www.sprfmo.int/data/record-of-vessels/

Vessels	
Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) List of Authorized Vessels	https://www.ccamlr.org/en/compliance/list-authorized-vessels
North Pacific Fisheries Commission (NPFC) Vessel Register	https://www.npfc.int/compliance/vessels/interim
Taiwan Fisheries Agency	https://www.fa.gov.tw/en/Record_of_Vessel/content.aspx?id=10&hk=30ddabdd-ecda-4788-8f2d-ca6655832442&param=pn%3d1 https://www.fa.gov.tw/cht/FOC/
Merchant Vessels of the United States	https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Inspections-Compliance-CG-5PC-/Office-of-Investigations-Casualty-Analysis/Merchant-Vessels-of-the-United-States/

If we identified vessels that participated in multiple encounters with fishing vessels, we conducted a web search and reviewed RFMO registries using information from the vessel’s AIS to determine if the vessel was a transshipment or bunker vessel.

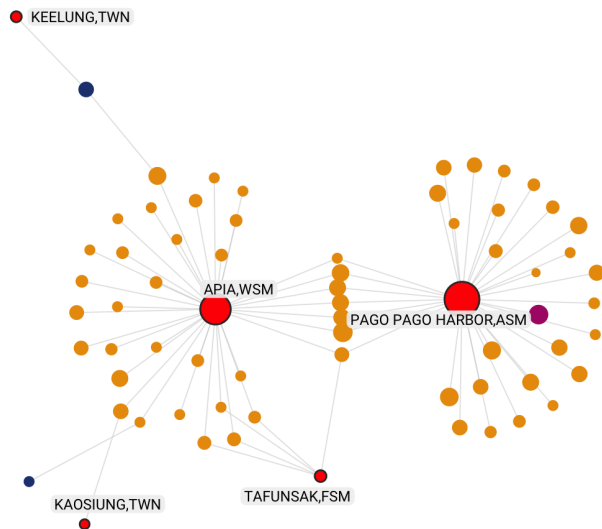
Finally, we used the convolutional neural network (Kroodsma et al. 2018), which predicts vessel class from vessel movement patterns to identify possible transshipment and bunker vessels. Vessels that were identified as likely transshipment or tanker/bunker vessels by the neural network were manually validated through web searches and RFMO registries. Vessel identities were further corroborated via the IMO as nearly all vessels could be matched to an IMO registry number.

Longline labor rights risk network communities

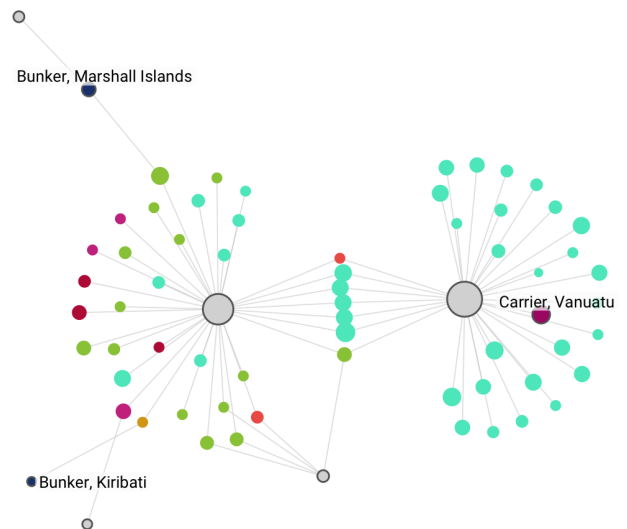
Below, in more detail, are communities outlined in figure 21. See section **Support Network for Risky Drifting Longline Vessels** for a fuller description.

Community 2

By Node Class



By Vessel Flag State



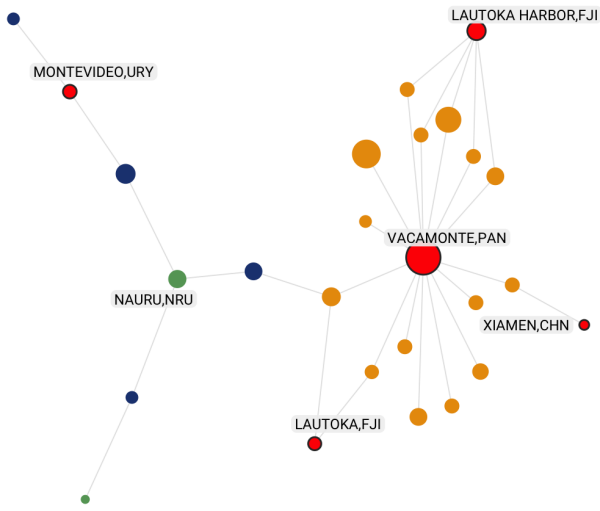
- | | | | | | |
|-----------|----------------------------------|-----------------|------------------|-----------|--------------|
| ● Bunker | ● Drifting Longline (Associated) | ● Port (Associa | ● Chinese Taipei | ● Vanuatu | ● Kiribati |
| ● Carrier | ● Drifting Longline (Risky) | ● Port (Risky) | ● China | ● Fiji | ● Micronesia |
- Others: American Samoa:1, Marshall Islands:1, Samoa:1*

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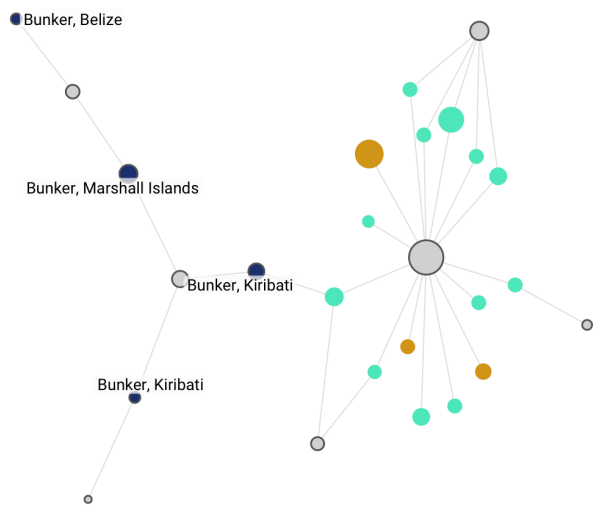
Community 2 represents longline vessels operating in the Pacific out of Suva (Fiji), Samoa and American Samoa. Those vessels operating out of Suva are primarily flagged to China, those operating out of American Samoa are primarily flagged to Chinese Taipei, and those operating out of Samoa are generally flagged to China and Chinese Taipei.

Community 3

By Node Class



By Vessel Flag State



- Bunker
- Drifting Longline (Associated)
- Port (Associated)
- Carrier
- Drifting Longline (Risky)
- Port (Risky)

- Chinese Taipei
- Fiji

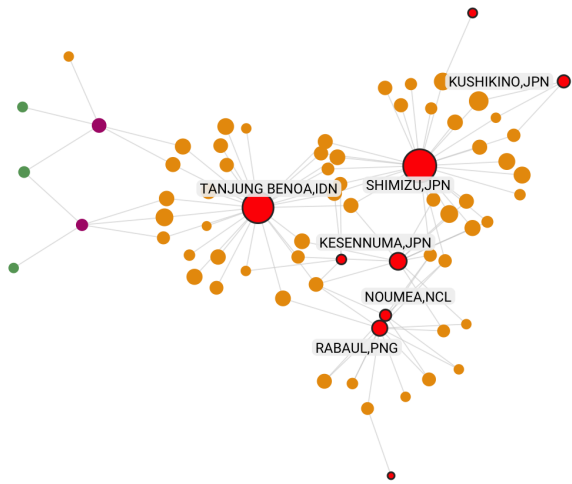
Others: Belize:1, Marshall Islands:1, Nauru:1, Papua New Guinea:1, Uruguay:1

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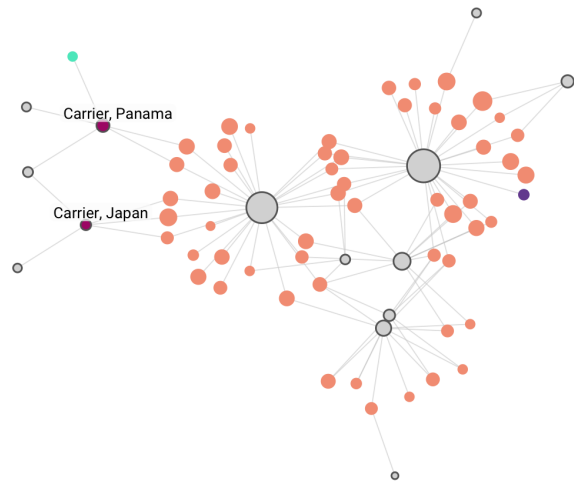
Community 3 represents vessels operating in the south and eastern Pacific region and signifies the presence of ports in Panama, Fiji and Nauru. Most of the longline vessels are flagged to Chinese Taipei with perhaps some connections to Kiribati-flagged bunker vessels.

Community 4

By Node Class



By Vessel Flag State



- Bunker
- Drifting Longline (Associated)
- Port (Associated)
- Carrier
- Drifting Longline (Risky)
- Port (Risky)

- Chinese Taipei
- Japan
- Republic of Korea

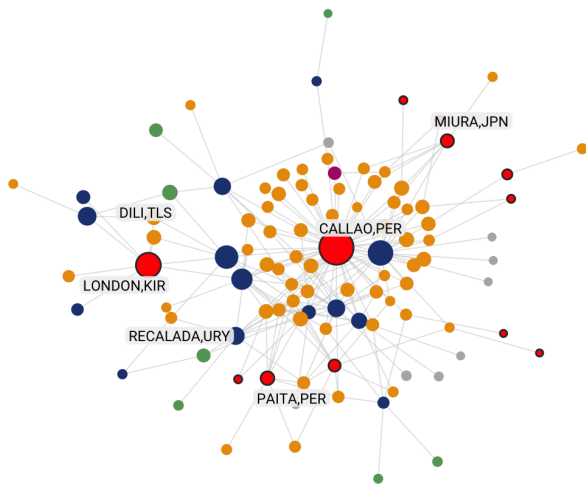
Others: Indonesia:2, Australia:1, Mexico:1, New Caledonia:1, Papua New Guinea:1, Thailand:1

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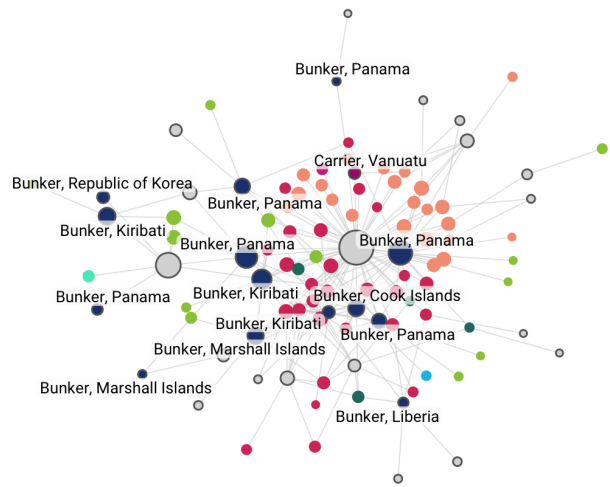
Community 4 represents higher-risk Japanese longline vessels operating out of ports in the western Pacific (Indonesia, Japan, New Caledonia). Few carrier and bunker vessels appear to support this community in direct ways.

Community 6

By Node Class



By Vessel Flag State



- Bunker
- Drifting Longline (Associated)
- Port (Associa
- Chinese Taipei
- Japan
- Spain
- Panama
- Carrier
- Drifting Longline (Risky)
- Port (Risky)
- China
- Vanuatu
- Portugal

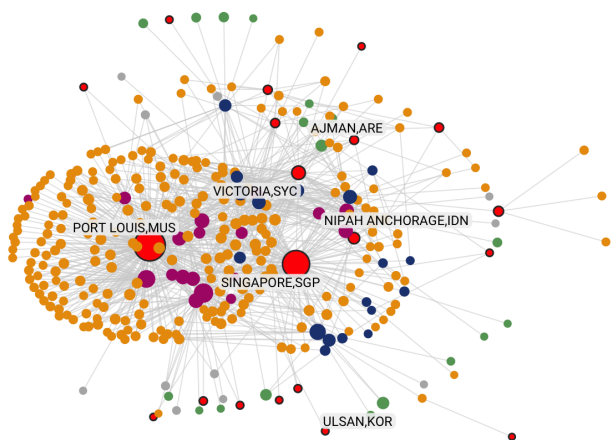
Others: Peru:5, French Polynesia:2, Marshall Islands:2, Canada:1, Chile:1, Cook Islands:1, Ecuador:1, Liberia:1, St. Lucia:1, Timor-Leste:1, Uruguay:1

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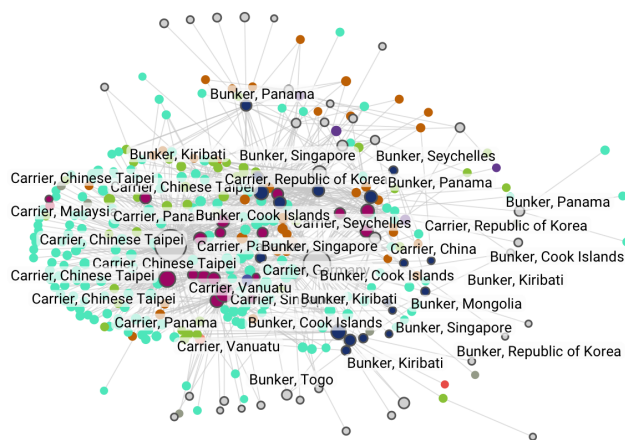
Community 6 includes a set of higher-risk vessels flagged to Spain and Japan and are associated with Peruvian ports, especially the port of Callao. The Spanish vessels are more closely linked to a set of Kiribati, Cook Islands and Panamanian bunker vessels, while the Japanese longliners are linked to a single Panamanian-flagged bunker vessel.

Community 7

By Node Class



By Vessel Flag State



- Bunker
- Drifting Longline (Associated)
- Port (Associated)
- Chinese Taipei
- Japan
- Seychelles
- Micronesia
- Carrier
- Drifting Longline (Risky)
- Port (Risky)
- China
- Republic of Korea
- Spain
- Honduras

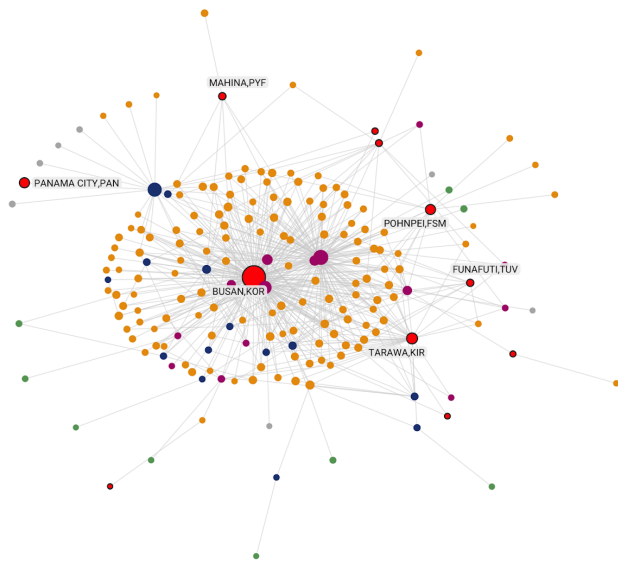
Others: Indonesia:7, Ecuador:5, Singapore:5, Cook Islands:4, Thailand:4, Malaysia:2, Mozambique:2, Russia:2, Sri Lanka:2, Tanzania:2, United Arab Emirates:2, Cambodia:1, Colombia:1, Falkland Islands:1, Germany:1, India:1, Kenya:1, Maldives:1, Mauritius:1, Mongolia:1, Oman:1, Papua New Guinea:1, Solomon Islands:1, Togo:1

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Community 7 represents longline vessels using ports in the Indian Ocean basin (Port Louis, Victoria, Singapore, and Indonesia). Many of these vessels are flagged to Chinese Taipei and the Seychelles, as well as China. A set of carriers flagged to Chinese Taipei, Panama, and Vanuatu appear to support many of the riskier vessels operating out of Port Louis, along with several bunker vessels. Another set of bunker vessels appear to operate on the periphery of this community.

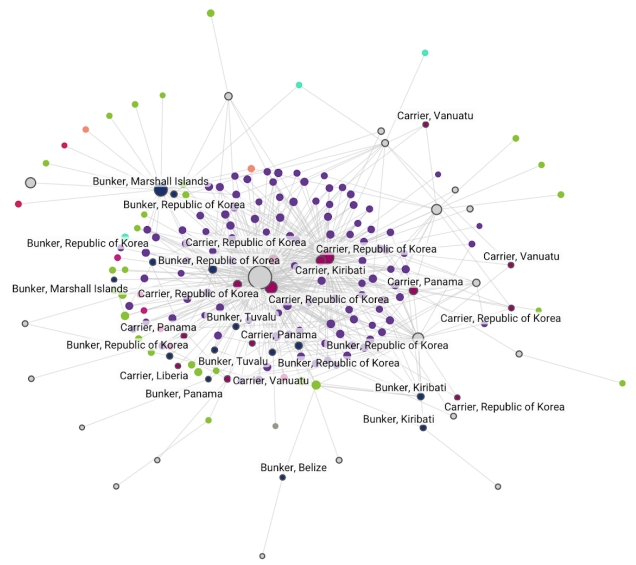
Community 8

By Node Class



- Bunker
- Drifting Longline (Associated)
- Port (Associated)
- Carrier
- Drifting Longline (Risky)
- Port (Risky)

By Vessel Flag State



- Chinese Taipei
- China
- Japan
- Republic of Korea
- Vanuatu
- Spain
- Other

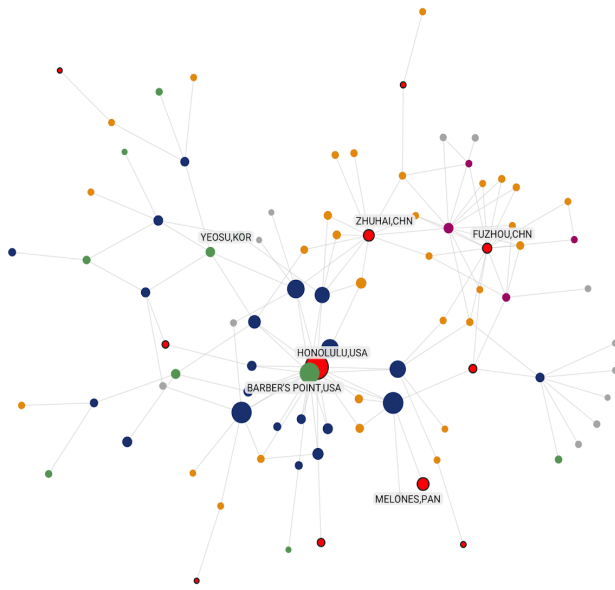
Others: Papua New Guinea:4, Tuvalu:3, Marshall Islands:2, Belize:1, French Polynesia:1, Liberia:1, Morocco:1, Solomon Islands:1

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Community 8 primarily represents South Korean longline vessels operating from Busan and, to a lesser extent, several Pacific ports. Most vessels are considered at higher risk of using forced labor and are primarily supported by Korean-flagged carrier and bunker vessels, though a few support vessels flagged to Vanuatu and Panama are also present. A small group of Chinese-flagged vessels are also included; however further analysis is needed to ascertain whether this is a true connection or driven by their use of the port of Busan.

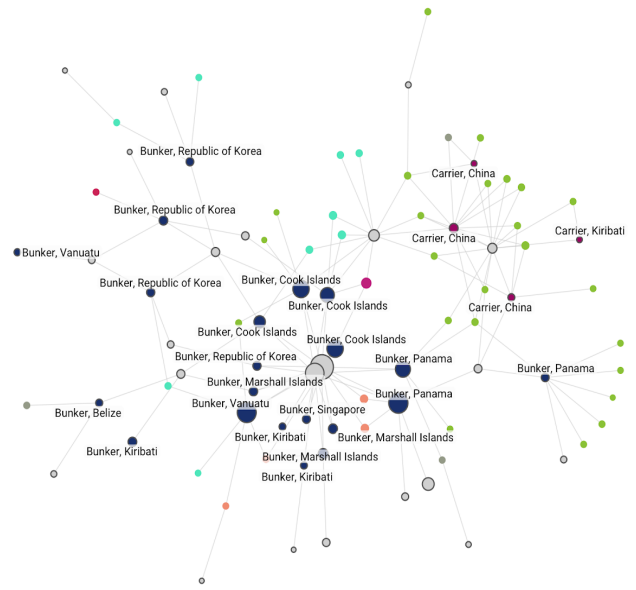
Community 9

By Node Class



- Bunker
- Drifting Longline (Associated)
- Port (Associated)
- Carrier
- Drifting Longline (Risky)
- Port (Risky)

By Vessel Flag State




- Chinese Taipei
- Japan
- Spain
- China
- Vanuatu
- Other

Others: Cook Islands:5, Marshall Islands:3, El Salvador:2, United States:2, Angola:1, Belize:1, India:1, New Zealand:1, Papua New Guinea:1, Singapore:1, Solomon Islands:1, United Arab Emirates:1

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Community 9 contains a large number of bunker vessels connected to ports in Hawaii, USA which are, in turn, linked to riskier longline vessels connected to ports in China and several Chinese carrier vessels.

 nate@globalfishingwatch.org

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Global Fishing Watch is an international nonprofit organization dedicated to advancing ocean governance through increased transparency of human activity at sea. By creating and publicly sharing map visualizations, data and analysis tools, we aim to enable scientific research and transform the way our ocean is managed. We believe human activity at sea should be public knowledge in order to safeguard the global ocean for the common good of all.

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