

Fisheries Network Analysis

DSAN 6400: Network Analytics

Morgan Dreiss

Liz Kovalchuk

Illegal, Unreported, and Unregulated (IUU) fishing remains one of the most significant threats to the sustainability of global fisheries and ocean ecosystems. While various nations and Regional Fisheries Management Organizations (RFMOs) have implemented measures to regulate fishing activities, the fishing sector continues to exhibit highly complex and opaque networks of relationships among vessels, companies, and regulatory bodies. These complexities challenge efforts to monitor fishing activity and detect potential illicit practices, particularly in regions such as the Western and Central Pacific, where over 3,000 vessels operate under the governance of the Western and Central Pacific Fisheries Commission (WCPFC). Network analysis has emerged as a valuable tool for mapping and analyzing the relationships within fisheries systems, providing insights that are often obscured in traditional datasets. Prior research has demonstrated applications of network analysis in examining vessel interactions, trade flows, and social and governance structures related to fisheries management. This paper reviews the existing literature on network analysis in fisheries contexts and explores how these methods might be applied to publicly available fisheries data from the WCPFC region. This work seeks to establish a framework for future research aimed at identifying structural patterns, potential risk indicators, and opportunities for more effective fisheries governance and enforcement.

Keywords: Fisheries; Illegal, Unreported, and Unregulated Fisheries; IUU Fishing; IUUF; Network Analysis; Western and Central Fisheries Commission; WCPFC; RFMO; fishing vessel registry

Affiliations: Georgetown University - Data Science and Analytics Masters Program

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1 Introduction

Over 90 million tons of seafood is harvested from our oceans every year (“Commercial Fishing, Global Fishing Watch” 2024), collected by nearly 3 million fishing vessels operating worldwide (Poortvliet 2024). With this immense level of fishing activity, there is a critical need for regulation to sustain fish stocks for future generations. While many nations and regions have implemented sustainable fishing practices and monitoring systems for decades, numerous countries and nefarious actors do not abide by these rules, contributing to growing global concern over Illegal, Unreported, and Unregulated (IUU) fishing.

This protein supply chain is unique in that it encompasses a diverse range of actors across the fisheries enterprise at multiple levels of procurement, production, and governance. Moreover, these actors are embedded in a complex web of regulatory frameworks that vary across jurisdictions and regions. Unlike domestic agriculture or meat production, commercial fishing often takes place hundreds—of even thousands—of miles away from the companies running operations and from the governmental bodies charged with oversight.

Understanding this complex system requires analytical methods capable of mapping the relationships and interactions among diverse stakeholders, vessels, and regulatory entities. With that in mind, this paper explores the potential of Network Analysis as a tool to show the intricate structures and connections within the fisheries sector.

This study reviews existing research and describes an initial approach for applying network analysis to publicly available fisheries data, focusing on the Western and Central Pacific region as a case study. While specific findings are beyond the scope of this project status assignment, this work sets the stage for identifying patterns and relationships that may inform future research, policy development, and strategies to combat IUU fishing.

1.1 Background

Certain fisheries, especially those which cross over multiple regions and jurisdictions, are governed by Regional Fisheries Management Organizations, or RFMOs. RFMOs are bodies that set regulations for fisheries and are responsible for holding their registered fishing vessels accountable for following the regulations set forth. RFMOs have designated regions and species within their field of management; see Figure [Figure 1](#), which is a map of the five tuna RFMOs¹ that are responsible for managing fisheries covering 91 percent of the world's oceans ([“What Is a Regional Fishery Management Organization. Pew” 2012](#)).

For the purposes of this paper, we will be scoping the analysis to the RFMO responsible for the Western Pacific, the **Western and Central Pacific Fisheries Commission (WCPFC)**. In order for vessels to fish for highly migratory species of fish (i.e. all types of tuna, marlin, etc.) in the Western and Central Pacific, they must be registered with WCPFC and follow its regulations. The WCPFC Convention Area covers over 12 million square nautical miles, or 20% of the Earth's oceans (see Figure [Figure 2](#)).

There are currently over 3,000 vessels registered under the WCPFC, with the most prominent flag states² being China, Japan, Chinese Taipei (Taiwan), and the Philippines ([“WCPFC RFV” n.d.](#)). The WCPFC regulates when, where, what, and how these vessels are allowed to fish, but only on the High Seas outside any other country's Exclusive Economic Zone (EEZ)³. In

¹Tuna is considered one of the most valuable fisheries in the world and all the tuna species are pelagic, ocean-going fish and considered highly migratory, making them a prime target for RFMOs.

²Flag State, or Flag State Jurisdiction, is defined as: “A State may exercise jurisdiction over a vessel that is registered with the State and flying its flag. This exercise of jurisdiction is based on the internationally recognized principle that a State may regulate the conduct of its nationals even when those nationals are acting outside of the State’s territory.” ([National Oceanic and Atmospheric Administration 2024](#))

³Exclusive Economic Zone (EEZ): “A coastal State has sovereign rights to the management of natural resources and other economic activities within its EEZ. It does not have sovereignty within its EEZ, so foreign vessels possess the same non-economic rights within a State’s EEZ as on the high seas.” ([National Oceanic and Atmospheric Administration 2024](#)) The EEZ extends from the country’s baseline to 200NM (or when meeting another country’s EEZ).

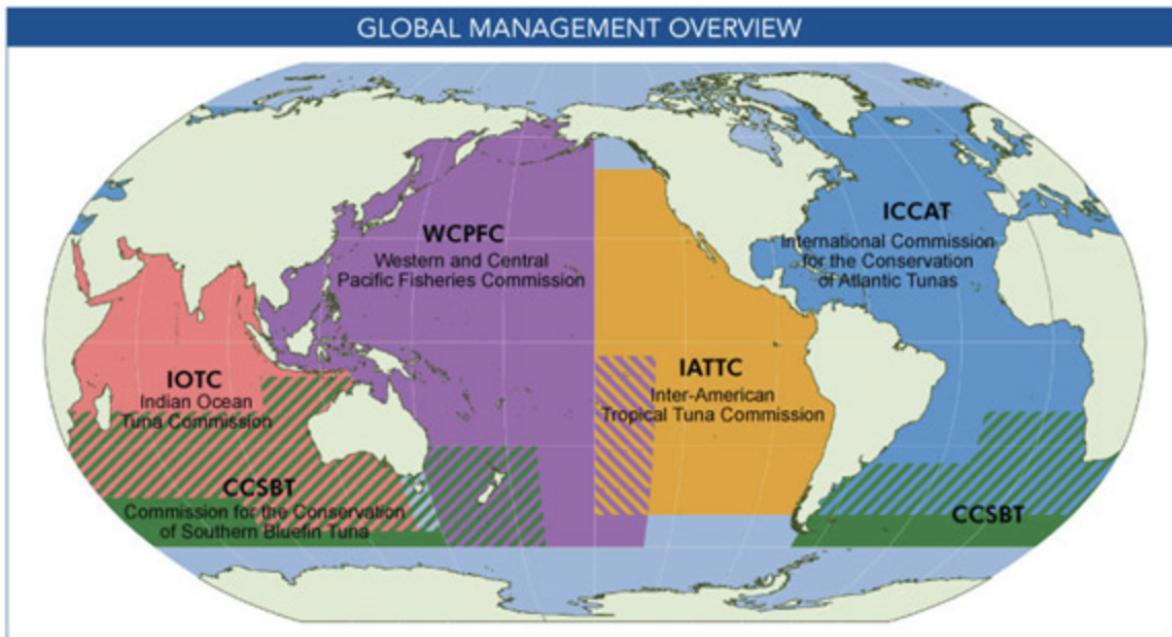


Figure 1: Global overview of tuna managing Regional Fisheries Management Organizations.

order for a vessel to be registered with WCPFC, it must also be flagged⁴ in a country that is a member of the WCPFC⁵.

With 26 member states and over 3,000 vessels, along with a large number of owners, operators, and corporations, the web of associations within the fisheries sector for just this RFMO is vast.

Using publicly available data on ship registration and associated information, we hope to examine the data for relationships that might indicate potential concerns or provide insight into the commercial fishing enterprise for this area of the globe.

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⁵WCPFC Commission Members:

Members - Australia, China, Canada, Cook Islands, European Union, Federated States of Micronesia, Fiji, France, Indonesia, Japan, Kiribati, Republic of Korea, Republic of Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Chinese Taipei, Tonga, Tuvalu, United States of America, Vanuatu.

Participating Territories - American Samoa, Commonwealth of the Northern Mariana Islands, French Polynesia, Guam, New Caledonia, Tokelau, Wallis and Futuna.

Cooperating Non-member(s) - The Bahamas, Curacao, Ecuador, El Salvador, Liberia, Panama, Thailand, Vietnam.

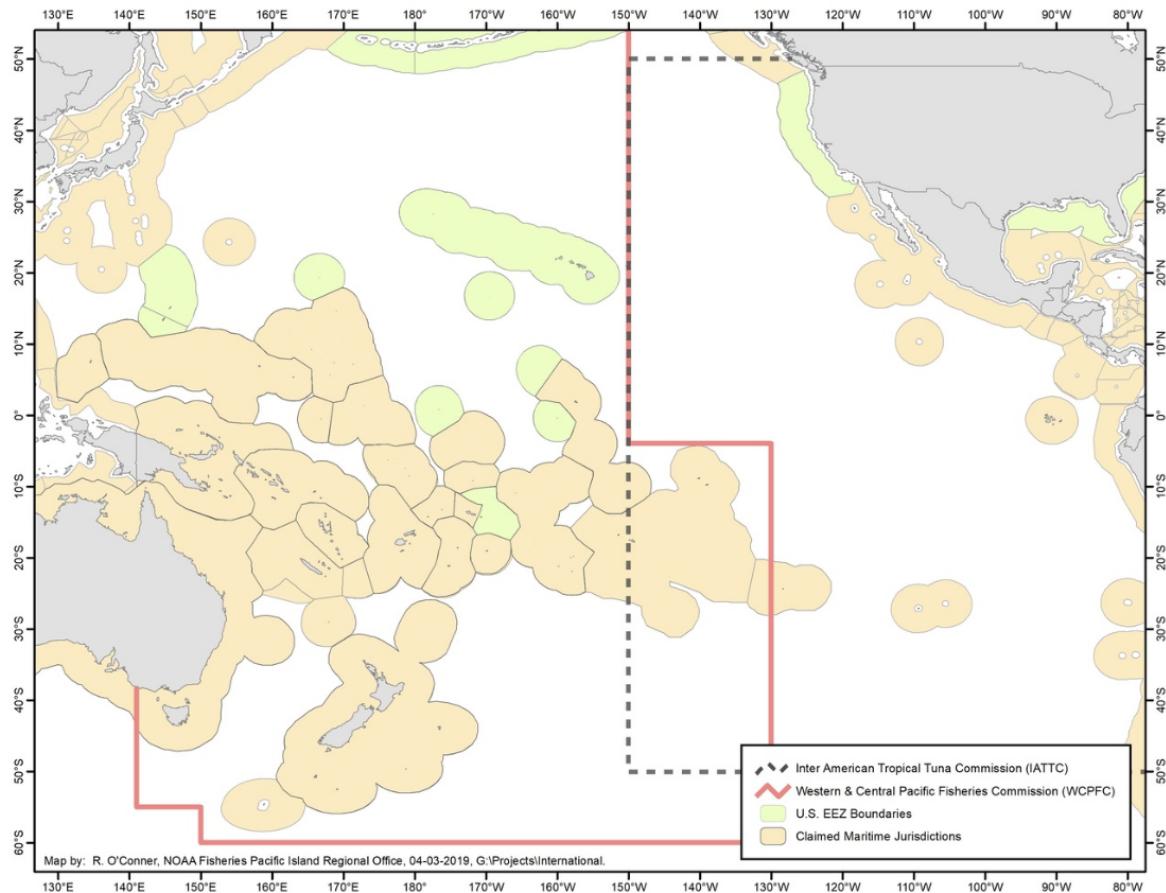


Figure 2: The WCPFC Convention Area spans the Pacific Ocean from roughly 141°E to 150°W.

1.2 Previous Work

Previous research has applied network analysis to study fishing practices and fisheries governance. Given the complex and layered relationships that exist between different entities and information flows, network-based approaches provide a way to model and visualize systems that would otherwise be extremely difficult to capture holistically. For instance, Dell’Apa et al. (2013) used Social Network Analysis (SNA) to analyze trade flows of spiny dogfish, revealing how global trade relationships impact regional conservation outcomes and suggesting that trade regulations could promote sustainability.

Network analysis has been used to relate information tied to vessels and their activities. For example, in Ford, Bergseth, and Wilcox (2018), researchers used SNA to identify key ships operating in the Indian Ocean fishing industry. By analyzing AIS data, they inferred relationships between vessels operating in close proximity and found that refrigerated cargo vessels (reefers) and bunkering ships played pivotal roles within the network, as evidenced by high eigenvector centrality scores. Network Analysis has also been used to understand vessel movements and behaviors outside of the fisheries scope. The highly cited Varlamis et al. (2021), explored the use of AIS data to build vessel-traffic networks. While their work focused more on visualizing maritime traffic patterns than directly addressing overfishing, it underscores how network-based data structures can enable analysis across diverse fisheries contexts.

Network analysis has also been applied to social and governance networks. For instance, Marín and Berkes (2010) examined co-management networks in Chilean small-scale fisheries, finding that power was highly centralized among government institutions and recommending policy changes to promote participatory governance. Such qualitative analyses underscore how network methods can extend beyond purely quantitative data to reveal institutional and social dynamics relevant to fisheries management.

The qualitative dimension remains important for future work that might follow quantitative analysis. As an example, Dell’Apa et al. (2014) expanded on earlier research to explore how stakeholder networks influence fishery management policies for spiny dogfish, highlighting the role of network structures in shaping effective governance.

Another study, Mulvaney et al. (2015), employed survey data to establish connections among stakeholders in the Great Lakes’ local fisheries network. While the study highlighted methodological constraints due to reliance on survey responses, it also showed that informal relationships accounted for a significant share of network connections, revealing an under-explored layer of fisheries governance.

A particularly promising area involves transforming fisheries data into network structures to reveal hidden dynamics. A critical component of Nogueira et al. (2023)’s analysis of fisheries in the Azores was the conversion of time-series catch data into network graphs. This time-sensitive approach enabled identification of key species associations and critical fishing nodes relevant to sustainable management strategies. Such techniques illustrate the potential for network

analysis not only to describe existing systems but also to support proactive recommendations for sustainability.

Across this body of work, researchers have applied diverse network approaches – from social networks and trade networks to vessel proximity networks – to uncover the structure and function of complex fisheries systems. These examples underscore the versatility of network analysis as a framework for exploring fisheries data. While each study focuses on a particular region or problem, collectively they demonstrate the value of network perspectives in understanding the multi-layered realities of marine resource use and governance.

This paper builds on these foundations by exploring how network analysis might be applied to the WCPFC fisheries context. However, our initial focus remains on developing methods and understanding the available data, rather than drawing definitive conclusions at this stage.

2 Data

Understanding the fisheries landscape in the Western Pacific requires integrating information from multiple domains. A large part of this analysis was creating this robust data set, which enabled the construction of a fisheries network and the application of network analysis methods to address the problem. Accordingly, we relied on datasets from international organizations, satellite-based monitoring platforms, and open-source geospatial repositories.

2.1 Data Collection

The first data source was the WCPFC’s Registry of Fishing Vessels (RFV) (“[WCPFC RFV](#)” n.d.). This is a list of approximately 3,000 vessels that are authorized to fish within the WCPFC’s Convention Area. The RFV contains the whole of the vessels’ registration information, including official name, flag state, identification numbers, home port, vessel type, and owner information.

Since the goal was to look at the actual fishing vessel activity, rather than just the registration of vessels, a second primary data source was introduced to create the network. Automatic Identification System, or AIS, is a near real-time record of the location of vessels. AIS was originally a collision avoidance tool for vessels over 300 tons, but some fishing vessels also utilize it. While many AIS viewing and collection sources are paid services, this analysis utilized open-source AIS information from (?) to identify vessels that fished within the Western Pacific.

Global Fishing Watch (GFW) applies their own “fishing detection algorithm based on changes in vessel speed and direction”, so that only the Apparent Fishing Effort was collected ([Global Fishing Watch 2025b](#)). Fishing vessel AIS activity was collected from the major fishing areas,

EEZs and High Seas Pockets⁶, within the Western Pacific. The exact areas and their boundaries can be found in Section 7.1. The activity was collected for each individual area from 01JUL2024 to 01JUL2025, with each observation identifying the vessel and how many hours they exhibited fishing activity in that time period. GFW's map from this same period can be seen in Figure 3. The full breakdown of Global Fishing Watch's fishing vessel activity algorithm can be found in their 2018 paper, Kroodsma et al. (2018).

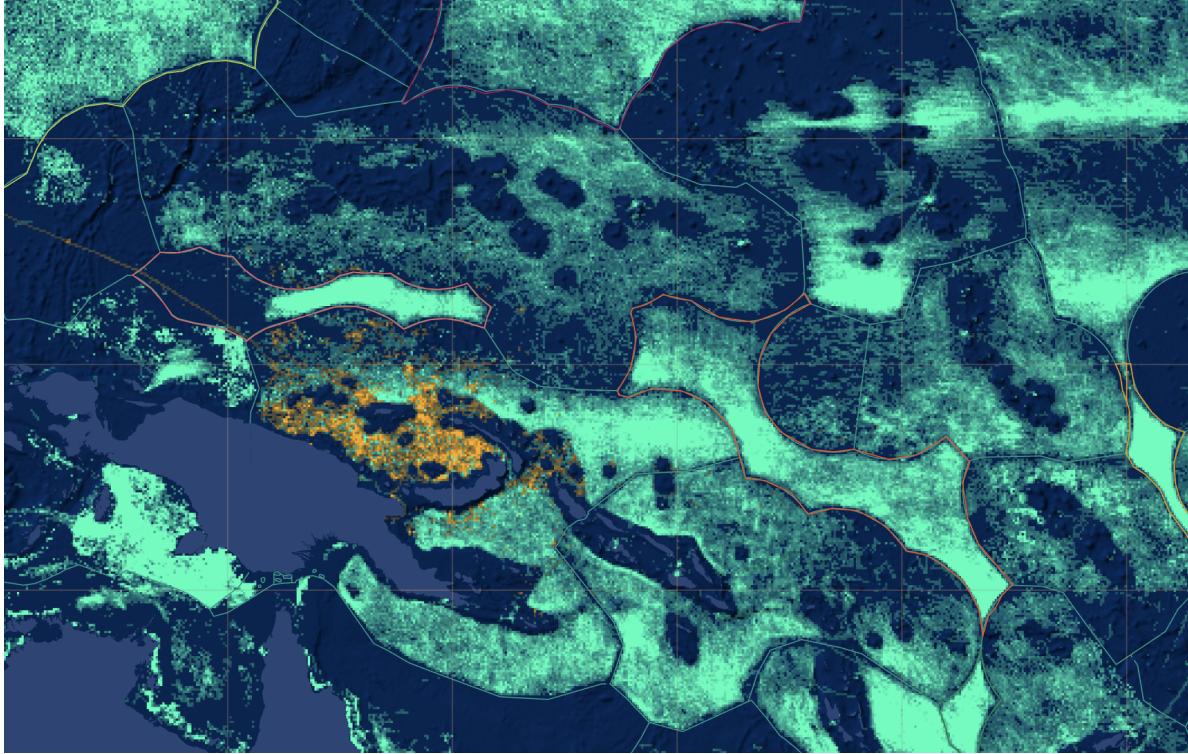


Figure 3: Global Fishing Watch Map with Apparent Fishing Efforts from 01JUL24 to 01JUL25.

It should also be noted that WCPFC also requires the use of Vessel Monitoring Systems, or VMS, for vessels fishing on the High Seas within the Convention Area. However, VMS is only accessible by those member states and agencies and organizations dedicated to fishers and is not publicly available. For that reason, VMS was not included in this analysis.

2.2 Data Cleaning

Before analysis, the data required several cleaning and preprocessing steps to ensure consistency and usability, along with preparing it for network creation. The Registry of Fishing Vessels was a complete data set, in that all the fields were filled out, but there was some variation of the

⁶High Seas Pockets are areas between county's Exclusive Economic Zones.

completeness within the fields. The field with the most inconsistency was the fishing vessels' owner's address field. Since the AIS data set that is paired with RFV has a significant spatial aspect, the locations of the owners/companies were of interest. The inconsistencies with this field stem from the fact that owners are spread throughout Asia (and the world) and many countries have different ways of writing addresses. To create uniformity in the owner location, this field was cleaned utilizing OpenAI's API, specifically the gpt-4o-mini model's chat responses ([OpenAI 2025](#)), to extract the approximate latitude and longitude location of the owner/company.

For readability, additional cleaning and standardization was conducted on the RFV. The fishing vessel types were extracted from Food and United Nations (FAO) ([2019](#)) and the home port information was cross referenced with WCPFC's list of full port names ([Western and Central Pacific Fisheries Commission \(WCPFC\) 2025](#)). OpenAI's API was utilized again to extract the approximate latitude and longitude location of the home port as well.

2.2.1 Geo-Spatial Data Preparation

Given the spatial nature of the problem, a key objective of the analysis was to map the fishing vessel activity network in relation to each vessel's home port and ownership location. Achieving this required precise spatial coordinates for all network nodes.

To establish node locations, fishing area geometries were used as a foundation. For Exclusive Economic Zones (EEZs), centroids⁷ were calculated from shapefiles provided by the Maritime Boundaries Geodatabase ([Flanders Marine Institute 2023](#)). High Seas Pocket geometries were manually delineated and extracted from the Global Fishing Watch map ([Global Fishing Watch 2025a](#)), and their centroids were similarly computed. Finally, the vessel ownership locations were calculated by spatial joins with the world's administrative boundaries of states and provinces ([Earth and Society 2012](#)). This allowed ownership locations to be grouped together on some level for easier visualization. Figure 4 shows the areas assessed.

2.2.2 Network Data Preparation

The final data set merged together the AIS data from the fishing areas and the vessel information from the RFV. To facilitate the network construction, each observation was a singular vessel fishing in a singular fishing area, with the vessel and area attributes included. Ultimately, this data set is an edge list with additional node and edge attributes. Here are the final fields of the dataset:

⁷Note: The centroids are used just for visual representation and no distances were computed from these figures.



Figure 4: Fishing Areas assessed for AIS activity in the Western Pacific.

Table 1: Final Data Set Edge List Fields

Vessel Name	Flag State	Fishing Area	Fishing Hours
Vessel Type	Homeport Name	Homeport	Homeport Country
Owner Name	Owner Address	Province/State	Owner Country
Owner Latitude	Owner Longitude	Owner	Province/State
		Homeport Latitude	Homeport Longitude

3 Methodology

Here is what we are planning on doing

3.1 Network Construction

Talk about about the network itself

Table 2: Node and Edge Types for all networks

Node Type 1	Node Type 2	Edge Relationship	Edge Attribute
A	B	C	G

Node Type 1	Node Type 2	Edge Relationship	Edge Attribute
E	F	G	G
A	G	G	NA

4 Results (or Findings?)

Results of our analysis

4.1 Geo-Spatial Analysis Results

Finally, a geo-spatial network was constructed utilizing the centroids of the areas and the approximate positions of the vessel's home ports. The geo-spatial visualization in Figure 5 with the fishing area nodes delineated from the home port nodes by color and the edge width characterized by the sum of fishing hours in that fishing area.

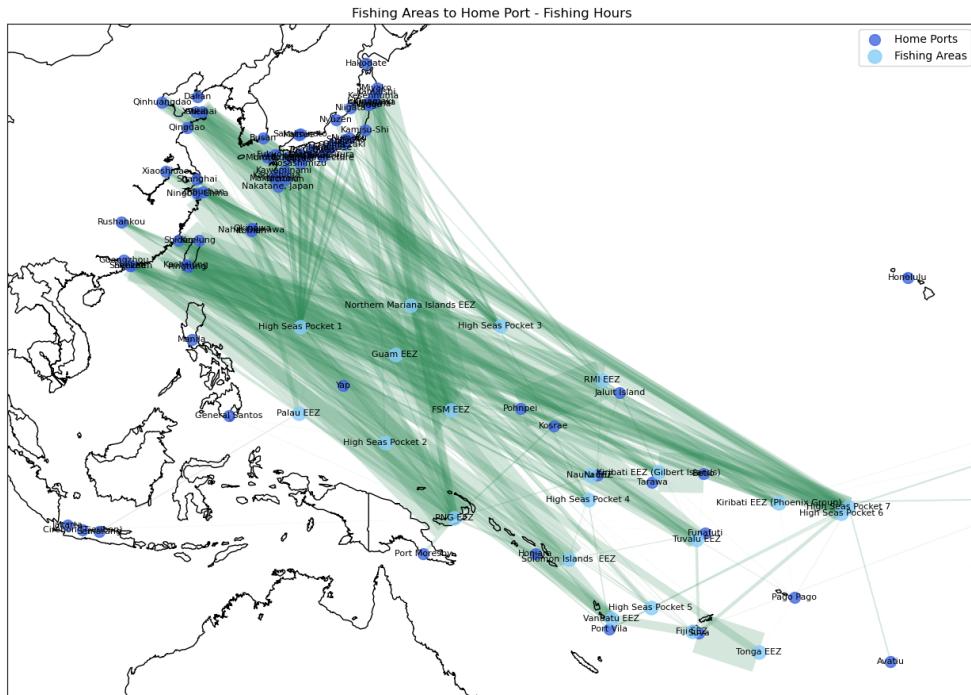


Figure 5: Fishing Area to Home Port Network Map.

This map alone is telling of the fishing vessel habits in the Western Pacific and clear patterns emerge. For example, port and fishing area pairs such as Pohnpei, FSM & the Marshallese EEZ

and Suva, FJI & the Tonga EEZ show that almost the entirety of that area's fishing efforts are by vessels home-ported in those ports, while other fishing areas have more varied vessel connections. Many of the regional relationships are what you would expect, with vessels sticking to areas that are closer to their home ports, however there are a few exceptions. Namely, the Papua New Guinea EEZ seems to be a popular fishing area for vessels from China, Taiwan, and Japan, with very little activity associated with PNG home-ported vessels. And alternatively, the Kiribati EEZ (Phoenix Islands) seems to be favored by Chinese and Taiwanese vessels and not the Japanese fleets.

Utilizing a community detection algorithm, additional insight can be drawn from that network map, Figure 6. With just the fishing hours and their corresponding areas assessed, the algorithm found three communities. The communities describe the behavior of three distinct fleets of vessels: the Japanese Fleet, Chinese/Taiwanese Fleet, and Pacific Island Nation Fleet. While there are some miss-matches when looking geographically, this analysis shows that vessels from those ports may not exhibit the same behavior as those closest to it distance-wise, but their behavior is akin to one of the other fleets.

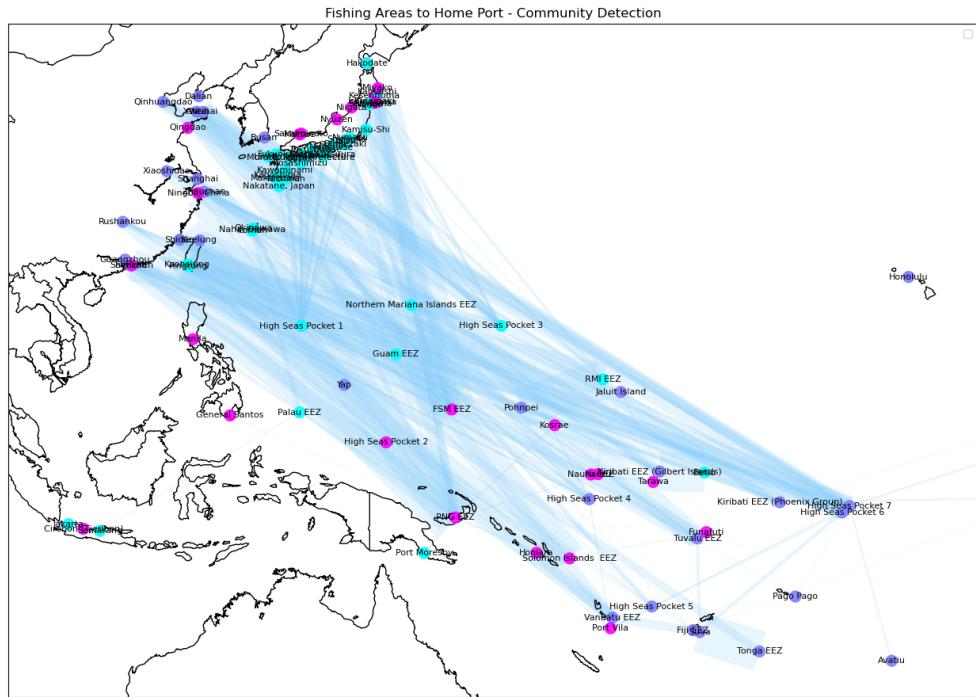


Figure 6: Fishing Area to Home Port Community Detection Map.

This analysis also looked at the relationship between vessel owner location and the home port of the vessel, however there was very little insights to be drawn, as the home ports were typically synonymous with the location of ownership. This is likely due to the fact that many companies have subsidiaries that located where their vessels are home-ported and that is what is listed on

the vessel registration. This relationship between ownership location and home port makes analysis of ownership to fishing area redundant with our original geo-spatial analysis and was not conducted. The home port to ownership location is displayed in Figure 7.

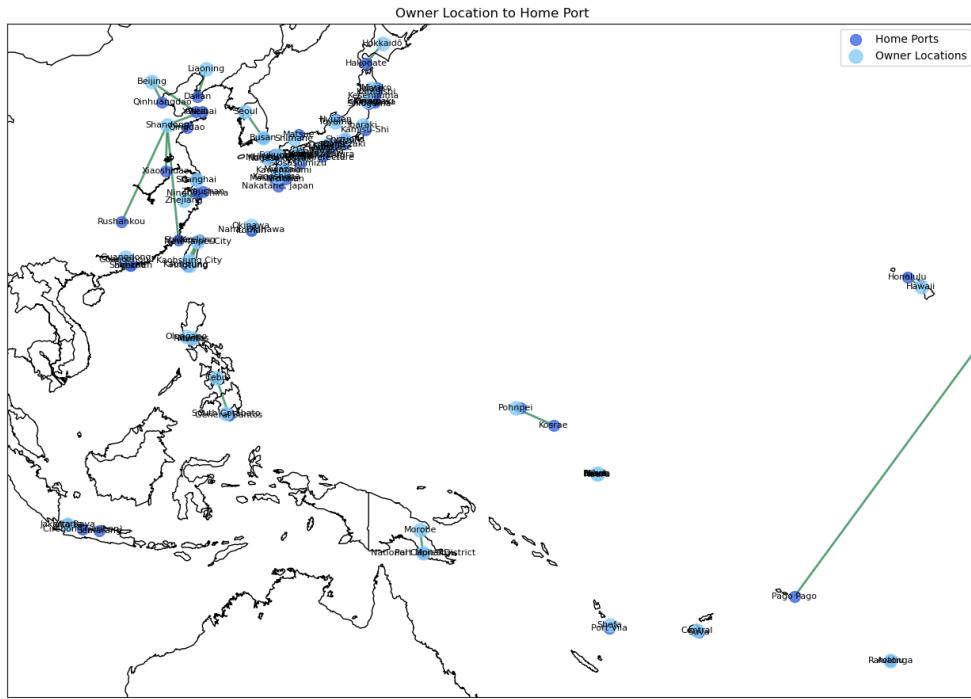


Figure 7: Home Port to Ownership Location Map.

5 Conclusion

Do we do a conclusion? or

6 Outlook

I think that makes more sense for our kind of paper, but I could be wrong.

Additional analysis opportunities:

This analysis was conducted utilizing open-source AIS data, however these methods could produce more robust results if additional data is introduced. Specifically, if the data was expanded beyond AIS into RFMO's Vessel Monitoring Systems (VMS) and even electronic intelligence (ELINT) feeds (such as CRFS ([2022](#))) further insights could be obtained.

Also one aspect that we did not touch on, but is relevant to this problem set is the role of fish carriers. Especially in relation to the geo-spatial analysis, where a vessel is home ported is not typically indicative of where the catch is landed. An additional analysis, using these same methods, focusing on fish carriers along with finding the proprietary information needed to determine where catch is actually landed would be highly beneficial to the fishing conservation community.

7 Appendix

7.1 Appendix 1: Fishing Areas

The AIS data collected for the apparent fishing activity was broken down by area, primarily Exclusive Economic Zones (EEZ) but also High Seas Pockets. The centroids of the EEZs were computed from Flanders Marine Institute ([2023](#)) using geopandas. For this analysis, the following areas were observed:

Observed Area	Description	Centroid
Fiji EEZ	Exclusive Economic Zone of Fiji	177.689346, -17.94847097
Federated States of Micronesia (FSM) EEZ	Exclusive Economic Zone of FSM	150.3224817, 6.768434442
Kiribati EEZ - 1	Exclusive Economic Zone of Kiribati (Gilbert Islands Group)	173.8878893, -0.25912361
Kiribati EEZ - 2	Exclusive Economic Zone of Kiribati (Phoenix Islands Group)	187.5460348, -3.731812109
Nauru EEZ	Exclusive Economic Zone of Nauru	166.1239638, -0.591130617
Palau EEZ	Exclusive Economic Zone of Palau	133.069498, 6.443930362
Papua New Guinea (PNG) EEZ	Exclusive Economic Zone of PNG	
Republic of the Marshall Islands (RMI) EEZ	Exclusive Economic Zone of RMI	167.4854677, 10.15136115
Solomon Islands EEZ	Exclusive Economic Zone of the Solomon Islands	163.6853914, -10.04465238
Tonga EEZ	Exclusive Economic Zone of Tonga	185.2341392, -20.22174869
Tuvalu EEZ	Exclusive Economic Zone of Tuvalu	178.1828785, -7.812542137
United States of America (USA) EEZ - 1	Exclusive Economic Zone of Guam	144.0026079, 12.9295752
United States of America (USA) EEZ - 2	Exclusive Economic Zone of Commonwealth of the Northern Marianas Islands	145.7393322, 18.28659832
Vanuatu EEZ	Exclusive Economic Zone of Vanuatu	168.5574292, -16.58523096

Observed Area	Description	Centroid
High Seas Pocket 1	Bounded by Japan's, USA's, Palau's, FSM's, and Philippines' EEZs	133.2661348, 16.03818414
High Seas Pocket 2	Bounded by FSM's, PNG's, Indonesia's, and Palau's EEZs	142.8799343, 3.058219655
High Seas Pocket 3	Bounded by 20° N to the North and RMI's, FSM's, and USA's EEZs	155.9543427, 16.04415883
High Seas Pocket 4	Bounded by FSM's, Nauru's, RMI's, Kiribati's (Gilbert Islands), Tuvalu's, Fiji's, Solomon Islands', and PNG's EEZs	165.9243784, -3.385867731
High Seas Pocket 5	Bounded by Fiji's, Vanuatu's, and Solomon Islands' EEZs	173.0194775, -15.37523716
High Seas Pocket 6	Bounded by the Equator (0°) to the North and Howland and Baker Islands' (USA), Kiribati's (Phoenix Islands), Tokelau's (New Zealand), Wallis and Fortuna's (France), Tuvalu's, and Kiribati's (Gilbert Islands) EEZs	-165.3957946, -4.886868152
High Seas Pocket 7	Bounded by the Equator (0°) to the North and Howland and Baker Islands' (USA), Kiribati's (Phoenix Islands), Tokelau's (New Zealand), Cook Islands' (New Zealand), Jarvis Islands' (USA), and Kiribati's (Line Islands) EEZs	-164.5540955, -4.161049605

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