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The role of the actors in the trade network structure of fishing products: The case of the shark market

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ABSTRACT

In this paper we study the influence of the structure of relationships in the commercial network of fishery products in the economic performance and profits distribution among actors, taking the shark market in Mexico as a case study. For this, fishermen, permit holders and traders were interviewed in the local, regional and main markets for shark products in Mexico. With the information obtained, a weighted network of the shark market was built, the main centrality indices and the monetary contribution of each actor to the commercial system in terms of economic profits were calculated. Through a stepwise multiple regression analysis, the variables that positively affect economic profits were identified. Our results show that shark fin exporters obtain the highest net unitary profits, while traders of shark meat and fillet presented the highest net profits. The organization of the actors (type), the quantity traded (Kg), the out-degree and out-closeness are the variables that positively affect the economic performance of the shark market. These findings agree with standard economic networks theory about the consequences of competitive and monopolistic market structure on the distribution of the economic returns of the food commercialization. The quantitative analysis of weighted networks in the trade of shark products gives rise to new insights to understand how economic profits are generated and distributed in a commercial system and how the actors involved are favored by said activity.

1. Introduction

Marine products are among the most traded products in the world (Smith et al., 2010; Crona et al., 2010), with profits and volumes that exceed trade of other goods such as cocoa, sugar, corn, coffee and rice (Smith et al., 2010; Watson et al., 2016). The trade in marine products is considered more important than the trade in cattle, and pork combined (Asche et al., 2015). Fishing as an economic activity is part of a supply chain in which foreign currency, direct and indirect jobs, raw materials for industries and food for the fishers is generated (INAPESCA, 2006; Dorantes-González, 2017). These supply chains are sequences of steps where users (related operators) carry out the process of transforming a product from its creation or extraction through processing to the final sale of the product and delivery to consumers (Jiménez-Sánchez, 2002). As any economic activity, the study of its economic performance is essential to adopt actions to improve the economic return, equity and social distribution of the activity. In this regard, profits are the usual economic performance adopted in fisheries studies and modelling (Clark, 2010).

Calculating profit in artisanal small-scale fisheries with largely informal market and no standardized reporting format (by government or tax offices) is hard, so this paper focuses on the economic aspects of small-scale fishing producer chains and measures the influence of the network topology and the positioning of the actors on the distribution of economic profits. Instead of the global network of fishery products, the local market is analyzed, through the construction of an inferential network model, quantifying the flow of product and economic profits that each actor contributes to the system and how they are distributed within it. The objective is to study the relationship between the position of the actors in the network and their economic profit, as well as the influence of the global topology of the network on the distribution of the profit. In this way, this work contributes to the analysis of the role of the network topology on the economic performance of the supply chain of seafood products and the profit distribution among the actors, from small-scale fisheries to fish-shops and exporters.

This study also has implications from a practical point of view.

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Unlike artisanal fishermen, traders have information and easier access to markets and often create exploitative social relationships with fishermen (Crona et al., 2010; Coronado et al., 2020). In this way, the transparency of the economic returns in the supply chain can be a mechanism to favor the sustainability of artisanal fisheries and the equilibrium of the distribution of the economic returns, as the agents who have such market information can make better decisions for production and trade (Purcell et al., 2017). Knowing the structural factors in the supply chain influencing the distribution of benefits will help the weakest agents to take actions that enhance the positive factors and mitigate the negative ones in order to achieve a better balance in the profit distribution.

1.1. Actors' role and distribution of economic returns

1.1.1. Fishermen

By means of a descriptive analysis of the value chain of 15 species of sea cucumbers in Fiji and Kiribati, Purcell et al. (2017) conclude that the difficulties of access to market information by artisanal fishermen influence the bargaining power that these actors may have and therefore the economic returns of the products they sell. The low yields for the artisanal fishermen activity cause them to remain in poverty and reinforce their little capacity to influence on product prices, at the same time that they depend on intermediaries, commonly a single actor, to reduce the time and effort to access national or international markets (Purcell et al., 2017; Kimani et al., 2020).

In this regard, Crona et al. (2010) also mention that commonly artisanal fishermen come to have agreements with intermediaries or traders, such as credits or monetary loans that are paid with daily fishing and are based on trust between the actors, but on many occasions intermediaries or traders use these agreements to "tie up" fishermen and force them to sell their products only to them. Coronado et al. (2020) mentioned this relationship between actors as a type of captive coordination, where producers depend on one or more traders and intermediaries to access markets and be able to sell their product.

The power to determine prices, maintain control of the market, choice and access to products and, mainly, the economic performance of each actor depends on the structural positioning of the actors within a social network (Kimani et al., 2020). The economic networks theory states that monopolistic situations, such as the one derived from captive coordination, decrease the economic performance of sellers (artisanal fishermen) in favor of buyers (traders) (Easley and Kleinberg, 2010). However, scientific empirical studies assessing the distribution of the economic returns in seafood trade are still scarce (Purcell et al., 2017), as many global fisheries suffer from a lack of transparency in terms of stakeholder participation, prices, revenues, benefit streams, and products.

This study aims to fill this gap and analyze primary and secondary information on the distribution and value of the fish product (shark) and its derivatives (fillet and fin) in Mexico from its first extraction to the last steps of the supply chain, in order to empirically test the topological factors in the supply chain influencing the distribution of economic returns from fishery products. For the reasons presented above, we expect that the potential number of buyers an agent have will be a key topological factor that determines the market power of the agent and therefore positively influences the share of economic returns received.

1.1.2. Exporters

In the recent decades, the exploitation of sharks has rapidly increased to meet the growing demand for shark fins (Ferretti et al., 2020), since in some parts of Asia they are considered luxury foods, being fin soup the most common shark food consumable in Hong Kong. On the other hand, Hong Kong is an important center for the shark fin trade, managing up to 50% of the global shark fin trade (Shea and To, 2017). For all shark species, meat is essentially a by-product of fin production, as the unit price of fins is, on average, about 10.8 times the price of shark meat (Ferretti et al., 2020). The international trade of these products is around USD 400 million annually, although the effort to track them has been hampered by the high processing of these goods in the markets (Van Houtan et al., 2020).

These high-value products are collected by artisanal and industrial fishermen and, although they have high value in international markets, they received low returns, as is the case of sea cucumber (Purcell et al., 2017). In the case of shark fins, trade is restricted by national or international regulations. For example, the General Law on Sustainable Fishing and Aquaculture (LGPAS) and the National Fisheries Charter (CNP) in Mexico, which are mandatory. On the other hand, the International Union for Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), despite acting at the international level, are not mandatory for countries that are part of these regulations (Dorantes-González, 2017).

The production and marketing restrictions due to existing regulations, as well as the lack of transparency in their commercialization, may limit the free access of firms to the fin market, favoring oligopoly and oligopsony capacity of exporters. In this case, the higher market power of these actors influences on the distribution of the economic returns (Sexton and Zhang, 2001), mainly harming artisanal fishermen without market power. Therefore, from this analysis we would expect that those actors that occupy the role of exporters monopolize the greater share of the economic returns in commercialization.

1.2. Social network tools to analyze seafood supply and value chains

Supply chains have been conceptualized as networks of actors (producers, distributors and consumers) who are connected through the transfer of products and are represented as a set of nodes (actors) and edges (transactions between actors). Through the application of quantitative measures, the key actors in the system can be identified, as well as its structure and operation (Hernández-Guerra and Pedroza-Gutiérrez, 2016). These networks of actors, better known as social networks, serve as primary channels for the flow of information and resources that facilitate human action (Barnes et al., 2016).

The analysis of these networks has proven to be helpful in the design of management strategies and facilitated the circulation of products through the identification of key actors (Zepeda-Domínguez et al., 2015) also called "bridger", which connect disparate groups or nodes within the network and allow the flow of information within of it (Hartley, 2010).

The degree to which the products is disseminated through social networks is greatly affected by the topology (structure and size) of the network (Barnes et al., 2016), which influences how resources circulate and how actors are connected in the network. For example, the position of an actor can allow or restrict access to a resource or a relationship with other actors to obtain products (Barnes et al., 2016; Packer et al., 2020).

Social Network Analysis (SNA) applied to the study of marine products has become popular in recent years; most of these studies have focused mainly on identifying and describing the topology of the network and the composition of the actors, in order to answer questions about the operation of the network. This is the case of Ramírez-Sánchez and Pinkerton (2009), who used the SNA approach to analyze the effect of resource scarcity on the structure of the information sharing network in fishing communities in Baja California Sur, Mexico. Barnes et al. (2016) used SNA to understand the structure of the tuna fishery and how the exchange of information between fishermen affects shark bycatch. Drury and Crona (2017) used the value chain approach to understand how the local market structures of artisanal fisheries in Zanzibar, Tanzania, can contribute to improving the livelihood conditions and food security of the actors. González-Mon et al. (2019) conducted a case study in Baja California Sur, Mexico, in which they mapped fish buyers and characterized the actors based on their commercial relationship patterns to study how the ability to adapt can be enhanced or affected by the ability to interact with other actors. Cruz et al traced the value chain of fishery products to identify all the actors involved in the commercialization process, from the fishery to the final consumer, to understand the commercial processes of the value chain of fishery products and thus support the traceability of marine products. Vidal-Hernández et al. (2019) used the SNA approach to analyze the structure of the commercial network of sea cucumber in Yucatan, identifying the key actors of the system, the connection between them and simulating hypothetical scenarios to know the modifications and repercussions that the entire system could have if the key actors disappeared.

Although all the studies mentioned above are representative of the application of SNA approach to seafood markets, they focus on the qualitative and topological description of commercial networks, as well as their relationship with production and ecological conditions. However, there are few studies that focus on measuring the influence of the topology of the chains of fishery products on the distribution of the economic returns to each actor within the network. In this context, Gephart and Pace (2015) analyzed the origins and destinations of marine products in the global market, considering the volume and economic value of the flow of products exchanged between countries, detailing the distribution of the economic profits within the commercial network. However, they do not delve into the analysis of the actors and their role or contribution to the system.

So, in this paper we provide one of the first applications of the weighted network analysis approach to the study of the marine products market, using the shark market as a case study and taking into account the characteristics of the actors involved in the system, network centrality indices and economic variables such as the flow of product and monetary value within the system.

2. Materials and methods

This study presents two approaches. We combine the qualitative analysis of information obtained through the application of interviews with fishermen, permit holders and traders of shark products with the analysis of quantitative data from social networks that define the structure and function of the commercial network. First, we mapped out the product exchange relations between the actors and, combining this information with the Social Network Approach, we characterize the main metrics of the network, identifying different types of actors, their role in the system and the flow of economic profits and product exchanged in the network.

2.1. The case study: the shark market

We selected the shark market (i.e., the total buyers and sellers of shark products and derivatives from the extraction to the final sold to retailers and exportation) in the northwest Mexico as case study since it is an important commercial activity ranked tenth among the most important fishing resources in Mexico in the last decade, with an annual catch of near 30,000 tons (SAGARPA, 2017), while globally Mexico ranks sixth among the largest shark product generating countries (Dent and Clarke, 2015; Dorantes-González, 2017).

Fishery products markets, according to García-Núñez (2008), are difficult to track. This is the case of the shark market, where derivative products such as fins and cartilage are mainly handled, in addition to oil, meat, skin and jaws, which are usually sent in mixed shipments and classified according to market requirements. This situation, and the presence of gaps and inconsistencies in the information from fishing landings (Dorantes-González, 2017) have compromised the correct evaluation of shark fisheries, mainly in developing countries such as Mexico (Saldaña-Ruíz et al., 2017). In Mexico, the artisanal shark fishery is considered a traditional activity with high socio-economic value that support many families.

As mentioned earlier, a supply chain or value chain is a sequence of activities in which a product is transformed, including extraction, processing, marketing, sale and delivery to the final consumer. In these sequences, different actors who specialize in a certain point of the process are involved, allowing to improve the quality of the product, generate jobs and add value for the benefit of the users and the market (Jiménez-Sánchez, 2002; Rosales et al., 2017). In this regard, the network of firms existing down and up-stream to any other firm can be defined as a supply network, which is a system where emergent patterns can arise (Choi et al., 2001).

Nowadays in Mexico the supply chain or supply network that make up the shark market are not known, as well as the actors involved, the relationships between them and the flow of profits that moves along the network. This study was approached from two perspectives, measuring the Total Profits of the network and the Profits/Kg which can give us a reference of the performance of the market at a total and product level.

2.2. Information sources

To learn about the structure of the supply shark network and the flow of economic profits in it, interviews were conducted during March 2019 with artisanal shark fishermen and permit holders in Baja California Sur, Mexico (during business hours 8am - 4pm). Other external traders were identified and interviewed during September 2019 including managers of warehouses selling shark and derived products in the Mercado de La Nueva Viga in Mexico City, the largest seafood market of Latin America, the Mercado del Mar in Zapopan, Jalisco, Mexico and in the local fish shops of the city of Tijuana, Baja California, Mexico (during business hours 3am - 1pm).

This interview (Supplementary Material) was structured to obtain information related to 1) suppliers and inputs, 2) resource extraction, 3) transformation of the resource and 4) purchase and sale. In addition to these sections, during each interview open questions were introduced to clarify and expand the responses of the interviewees.

For this work, 29 actors of the shark market in Mexico were personally interviewed in March and September 2019, including fishermen (6), wholesale and retail traders (20), fish shop managers (2) and fin collectors (1). From these 29 interviewees, additional information from other 65 actors related to the shark trade in Mexico was obtained, as well as weekly data on the flow of product (quantity) and economic benefits (profits) among the actors that make up the shark market and derivative products. All these data from the 94 actors related to the shark market were considered for network analysis and stepwise regression.

The artisanal fishermen deliver the sharks caught to a trader, who is in charge of sending the product to El Mercado de La Nueva Viga in Mexico City, El Mercado del Mar in Zapopan, Jalisco and to local fish shops in Tijuana, Baja California, so we continue to apply interviews in these mentioned sites.

The authorization of each interviewed and the general administration of each market was requested for the application of the interviews, informing the scope and the future use of the information provided, each actor interviewed received a code name in the database to identify him and protect his identity.

2.3. Data analysis

With the data obtained from the interviews, a matrix of weekly commercial relationships between the actors was made including variables indicating the economic performance, the actors' features and the network metrics (Table 1). For the calculation of profits, we estimate the income as the monetary quantity ($ USD) resulting from the weekly sale of the resource (Price*Quantity), and the total costs as the sum of all weekly marketing/production running costs (provisioning and maintenance of the boat, fuel, bait, purchase of the product, salary of employees, transportation and storage of the product, rent of warehouse) ($ USD).

The network metrics were calculated with the igraph package (Csardi and Nepusz, 2006) in the statistical program R version 3.6.1 (R

Table 1
Variables used to perform economic analysis. The network metrics are calculated with the igraph package.

Variable	Description
Economic performance	
Net Profits ($ USD)	Monetary amount ($ USD) resulting from subtracting product and operation costs and total costs from income, can be handled as the net profit from weekly marketing.
Net Unitary Profits ($ USD)	Monetary amount ($ USD) or net profit obtained by market players for marketing each kilogram of product per week.
Actors' features	
Quantity (Kg)	Quantity of the resource marketed weekly during the peak season
Presentation	Modality in which the shark resource is sold (Meat, Fillet or Fin)
Type of actor	There are six types: Artisanal Fishermen, Trader, Fishing Company, Permit Holder, Fish Shop and Exporter
Network metrics	
Eigen-centrality	It measures the influence of a node on the network and the ability to connect with other nodes.
Out-degree	Number of nodes to which each actor sends shark products.
In-degree	Number of nodes from which each actor receives shark products.
Betweenness	Indicates the ability of a node to act as a bridge between pairs of nodes and communicate products.
In-closeness	It measures the accessibility of a node to the other nodes in the network considering the input of shark products.
Out-closeness	It measures the accessibility of one node to the other nodes in the network considering the output of shark products.
Constraint	It aims to identify individuals who are isolated in the network and who have low chances of connecting with other nodes

Core Team, 2019) using information regarding the actors (actor, quantity, origin, and destiny). Then, the network represents the supply chain of shark products. The centrality indices were calculated by taking the amount of product sold between actors as the weight of the interaction and the direction in which the product moves within the network, that is, the indices were analyzed as part of a directed and weighted network.

Among the network topological indices, there is the eigen-centrality, which measures the influence that a node has when connected with nodes that, in turn, are connected to many nodes. The centrality of an actor in a network can indicate a leadership capacity, popularity, or a good reputation within the network and the greater its centrality value, the greater the possibility of obtaining power and influence within the network (Zhang and Luo, 2017).

The degree centrality measures the total number of direct connections a node has with other nodes in the network (Zhang and Luo, 2017). In this case we use two degree centralities, one for incoming connections (in-degree) and one for outgoing connections (out-degree). A node with a high in-degree indicates that this node is in a good position to receive product and those nodes that present a high out-degree could be considered as important sources of shark products (Gómez, 2019).

High values of betweenness centrality indicates that the node is in the path through which other nodes must pass to share products along the network (Zhang and Luo, 2017). In this way we can identify those nodes that have an important role in the network by connecting nodes or groups of nodes that are separated and functioning as a bridge for the transfer of shark products between actors (Junker and Schreiber, 2008; Wilson and MacDonald, 2018). La Ola et al. (2020) mentioned that actors that are functioning as bridges by presenting high betweenness values in a network system are considered key actors of the system.

Another important centrality metric that were taken into account for this work is the in- and out-closeness. The values of this metric vary from 0 to 1, indicating that nodes with values close to 0 are further away from the rest of the nodes in the network and nodes that have values close to 1 are only one step away from any other node in the network (Goldstein and Vitevitch, 2017).

The last of the topological metrics analyzed in this case study is constraint, in which the highest values indicate the nodes that are restricted or isolated in the network, presenting the least possibilities of connecting with other nodes or groups of nodes (Everett and Bogartti, 2020).

Once the economic variables resulting from the interviews and the estimated network variables were calculated, the determining factors of the net profits and net unitary profits (profits/Kg) variables were estimated. The aim of estimating profit in unitary terms is to find factors influencing profits independently of the firms' size (measured as the volume of transaction). A stepwise regression model following the Ordinary Least Squares (OLS) procedure were used to ensure a correct data fit (Jenkins-Smith et al., 2017). The stepwise regression was analyzed using the package "MASS" (Venables and Ripley, 2002) and "lmtest" package (Zeileis and Hothorn, 2002) in the statistical program R version 3.6.1 (R Core Team, 2019). It is important to note that the variables "Type of actor" and "Presentation" were analyzed as categorical variables since different levels of organization were identified within these variables (Table 1). In addition, the values of the stepwise regression analysis for these two independent variables are displayed in comparison with a base reference value belonging to one of the categories that integrate the independent variables "Type of actor" and "Presentation". We propose a standard multiple regression model (Wooldridge, 2013). The econometric model is as follows:

$$Y_i = \beta_0 + \beta_Q \cdot \text{Quantity}_i + \beta_P \cdot \text{Presentation}_i + \beta_T \cdot \text{Type of Actor}_i + \beta_N' \mathbf{N}_i + \varepsilon_i,$$

Where Yi is the "Net Profits" or "Net Unitary Profits" of observation (firm) i, β_0, β_Q, β_P and β_T are the intercept and coefficient parameters for the quantity and categorical variables, $\mathbf{N}_i$ is a 7x1 vector of the network metrics in Table 2 corresponding to observation i, $\boldsymbol{\beta}_N$ is the corresponding coefficient of these variables, and ε_i is the residual error. The standard minimum level of significance (0.1) for the coefficient of the independent variables was taken in the stepwise regression analysis. In addition to this, 19 nodes that correspond to groups of traders or local markets were eliminated from which complete data regarding costs and profits could not be obtained, therefore only 75 of the 94 nodes obtained during the interviews were considered for the stepwise regression analysis.

3. Results

3.1. Interviews

The six fishermen interviewed indicated that shark capture is their main source of economic income and in many cases, the only option of work in the area where they live.

The price range varies between $0.3 USD/Kg and $1.32 USD/Kg having as main target species of their fishing the thresher sharks (*Alopias* sp.), silky shark (*Carcharhinus* sp.), hammerhead sharks (*Sphyrna* sp.) and a variety of small and juvenile sharks, less than 150 cm in total length, that are grouped as "dogfish" he artisanal fishermen deliver the sharks and "dogfish" caught to a trader, who is in charge of sending the product to El Mercado de La Nueva Viga in Mexico City, El Mercado del Mar in Zapopan, Jalisco and to local fish shops in Tijuana, Baja California, so we continue to apply interviews in these mentioned sites.

The Mercado de La Nueva Viga has 256 warehouses dedicated exclusively to the trade of marine resources of which, according to the general administration, less than 10% of the warehouses are dedicated to the shark trade. In this market we identified and interviewed 11 main traders of shark and derived products, which mostly market shark and "dogfish" in whole, dry/salted, fresh fillet and fin presentations, with prices ranging from $1.78 USD/kg in the whole presentation to $20.40 USD/kg in the fin presentation. In this market, shark products are traded between the traders and the different warehouses. Then, we located a single trader who is dedicated to collecting and buying shark fins from the warehouses and sells them to exporters who are in charge of bring

Table 2
Estimates of the main economic variables and network indices analyzed. The nodes that correspond to groups of traders or local markets in Fig. 1 have not been included.

Variable	# Node	Estimate	Type of actor	Presentation
Total Profits ($ USD)	3	$39,406.17	Trader	Meat
	78	$23,214.29	Artisanal fishing	Meat
	16	$12,295.92	Trader	Fillet
Profits/Kg ($ USD)	35	$38.41	Exporter	Fin
	36	$38.41	Exporter	Fin
	37	$38.41	Exporter	Fin
Quantity (Kg)	3	50,000	Trader	Meat
	78	35,000	Artisanal fishing	Meat
	44	26,000	Trader	Meat
Eigen-Centrality	12	0.514	Trader	Meat
	14	0.411	Trader	Fillet
	13	0.147	Trader	Fin
In-Degree	3	9	Trader	Meat
	6	6	Fish shop	Fillet
	2	6	Trader	Meat
Out-Degree	3	8	Trader	Meat
	42	6	Trader	Meat
	4	6	Trader	Meat
Betweenness	13	185	Trader	Fin
	3	134	Trader	Meat
	2	78	Trader	Meat
In-Closseness	5	0.000114	Artisanal fishing	Meat
	7	0.000114	Artisanal fishing	Meat
	23	0.000114	Artisanal fishing	Meat
Out-Closseness	13	0.000118	Trader	Fin
	33	0.000114	Exporter	Fin
	34	0.000114	Exporter	Fin
Constraint	85	1	Artisanal fishing	Meat
	87	1	Artisanal fishing	Meat
	89	1	Artisanal fishing	Meat

this product to the international market, mainly the Asian market. The information of the exporters was obtained only through the fin collector and the price range was obtained from official data from FAO (2021).

Moreover, nine traders of sharks and fish products were identified and interviewed in the Mercado del Mar. The main sales presentations in this market are whole and fillet with oscillating prices between $2.04 USA/kg - $4.08 USD/kg in the whole presentation and $4.84 USD/kg - $7.14 USD/kg in the fillet presentation. As in the Mercado de La Nueva Viga, the commercialization of shark products among the traders and stores of the Mercado del Mar is a common activity.

In the city of Tijuana, Baja California, Mexico, eight fish shops dedicated to the shark trade were identified, but only two fish shops managers agreed to be interviewed. The actors mentioned that the main shark presentations that are marketed are whole and fillet with prices ranging from $1.78 USD/kg - $2.04 USD/kg and $4.84 USD/kg - $5.86 USD/kg respectively. They also indicated that their sale is retail and wholesale which includes other fish shops in the town.

3.2. Network analysis

3.2.1. Descriptive statistics

The commercial shark network in this study consists of 94 nodes (actors) and 137 edges (connections) present between the nodes (Fig. 1). This network is a sample of the global shark distribution network in Mexico. Table 2 presents the most relevant players in the shark market network according to the metrics contemplated. It is important to clarify that 19 nodes were not included in Tables 2–3 and in the multiple regression analysis because they were not a single actor, but a commercial complex including a large number of actors.

As shown in Table 2, of these 94 actors, nodes #3, #78 and #16, which are a trader of the Mercado del Mar in Zapopan, Jalisco, a group of artisanal shark fishermen in the town of San Carlos, Baja California Sur and a trader of the Mercado de La Nueva Viga, respectively, obtained the highest values of total profit ($ USD). This is expected since these three nodes also showed the main volumes of product marketed with 50 tons (t), 35 t and 14 t respectively. However, node #44, other trader of the Mercado de la Nueva Viga, commercializes higher volumes than trader #16. The reason for the higher profitability of node #16 lies in the type of presentation (fillet) of this trader, which creates an added value to the product.

Node #3 is particularly relevant. This node is among the main nodes in five of the 10 estimated variables (Table 2). Selling shark and "dogfish" every week, node #3 has the highest degree centrality, with 9 connections in the in-degree estimation and 8 connections in the out-degree estimation, and it buys its product mainly from artisanal producers and sells it to local markets and other traders (Fig. 1).

Actors #35, #36 and #37 are dedicated to the export of Shark Fin to the Asian market and presented the highest values of Net Unitary Profits ($ USD). The three exporters present the same amount of Net Unitary Profits since they obtain their product from the same node #13 and, in the absence of more information, we assume the quantity is equally shared among exporters. Node #13 is a fin collector of the Mercado de La Nueva Viga in Mexico City and the only actor in our commercial network that has contact with actors that are dedicated to the export of Mexican products to the Asian market, mainly to Hong Kong.

Fig. 1 shows two detached parts of the network, the first corresponds to the trade of node #88, which is an artisanal fisherman who removes the shark fin and sells it separately to node #20, which is a permit holder who sends this product to node #21, in the American international market, then, the node #88 sells the shark meat to the node #24 who transforms it into fillet and distributes it locally to node #25. The other detached part of the main network includes node #49, which is a permit holder that sells shark meat to nodes #50 and #51, who transform this product into fillet and sell it to the local market.

Nodes #85, #87 and #89 correspond to artisanal fishermen from the town of Santa Rosalía in Baja California Sur and show the highest constraint estimate (Table 2), indicating that these three nodes are the most isolated throughout our network system, in the same way they show the lowest values of the degree, closeness, betweenness and eigen-centrality. These three nodes mentioned to us during the interviews that they deliver their product to a single actor of the network (#86), as well there is a buy/sale agreement through a personal treatment between the actors involved, in addition to being #86 the only shark buyer in that study area and the only option of access to the local market.

The nodes #12, #13 and #14 which are traders dedicated to the commercialization of sharks in the presentations meat, fin and fillet, respectively, present the highest values of eigen-centrality, showing the influence that they can have within the network by being connected with nodes highly connected to other actors such as #11 which corresponds to the Mercado de La Nueva Viga, where most shark transactions are made.

3.2.2. Interpretation of the network metrics

Zhang and Luo (2017) presented a table of interpretation of

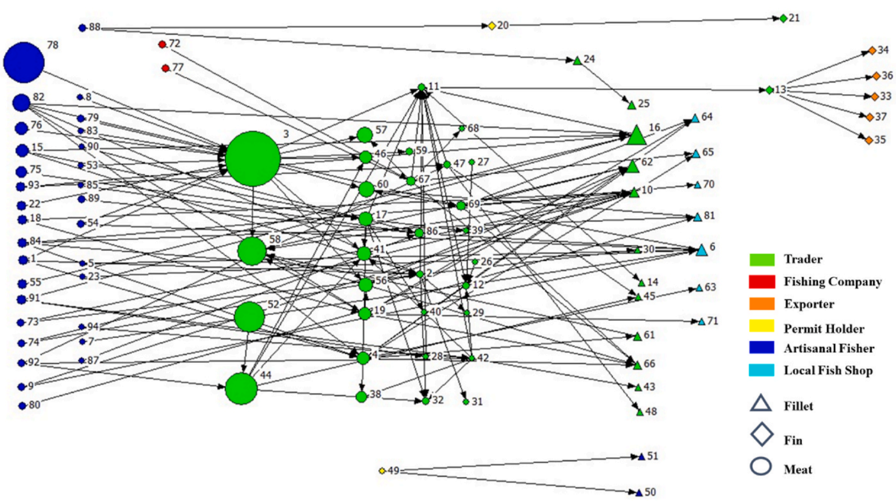

Fig. 1. Diagram of the commercial network of the shark market and its derived products in Mexico. Each node corresponds to a player in the shark market and each arrow indicates the direction of the flow of product traded between the actors. The size of the nodes corresponds to the total amount of shark product traded between the actors. The colors indicate the type of actor identified and the shapes of the nodes indicate the presentation of the product that each actor trade within the network. All the nodes correspond to individual actors, except for some cases that correspond to commercial complexes that include several actors, these are the traders: #58, #52, #57, #46, #60, #41, #56, #38, #11, #59, #40, #32, #20, #68, #39, #29, #31, #25, #21.

combined network values that we reproduce adapted to the results of the case study (Table 3). In particular, those nodes that have a high degree, but a low betweenness show redundancy in their connections, as is the case with nodes #4, #17 and #19 with degree values of 9, 8 and 8 respectively and low betweenness estimations of 7, 18 and 19 respectively. Following Jenssen and Greve (2002), redundancy within this network occurs when actors constantly trade with each other, which we can roughly see in the fourth level (from left to right) in Fig. 1. The low betweenness tells us that these three nodes do not play an important role as bridges within the commercial network.

On the other hand, the nodes with high betweenness, but few connections with other nodes (low degree) are crucial and supporting actors for the flow of the network, as would be the case of node #13 by presenting a betweenness value of 185 and a degree of 6. As mentioned above, this node is the only one that connects with actors that are engaged in the export of shark fin to the Asian market, so, in addition to being a crucial node for the transfer of shark products within the network, it is an important actor for the transfer of shark products outside the network and to other commercial systems.

Those nodes with high betweenness and low closeness are hoarding the network connections when connecting with nodes that are disconnected from the others, in that case we observe in Fig. 1 and Table 2 that traders #2 and #3 do this role in the way they connect with a large number of actors in the network, of which many are producers or artisanal fishermen.

Zhang and Luo (2017) mention that when nodes have a high closeness, but low degree it is because these nodes are connected to nodes that are important or very active actors in the network. This is the case of exporters #35, #36 and #37 that are only connected with #13 who intermediate in two steps with the main market in Mexico. Similarly, when they have a high closeness and low betweenness it is due to the fact that in the network there are many ways of sharing products and these nodes are close to a high number of actors, however, many other nodes are also nearby. This is the case of artisanal fishermen #5, #7, #23 (second level from left to right in Fig. 1), which have only one connection each and almost null value of the betweenness index.

3.3. Multiple regression analysis

In this paper, the economic performance of each actor was measured from two perspectives, the Net Profits ($ USD) and the Net Unitary Profits ($ USD) which show us complementary indicators of the performance of the shark market, both globally and profitability per unit of product. For the independent categorical variables “Type of actor” and “Presentation”, the categories “Trader " and “Fin”, respectively, were used as base reference to indicate those categories that present significant positive or negative effects on the dependent variables.

The results of the regression model estimation (Table 4) indicate that the independent variable that has the greatest positive effect on net profits is the “Exporter” category. Specifically, assuming all other variables identical, the net profits of exporter actors are on average $1.054 greater than the net profits obtained by actors belonging to the category “Trader”. However, the net profits of the actors with “Meat” presentation are on average $0.792 less than the actors with “Fin” presentation (Table 4).

As expected, the variable Quantity (Kg) show a positive influence on Net Profits, with an increase of 0.852 units for each unit increase (Kg) on the scale of the variable Quantity. In the same way the category “Artisanal Fishermen” has a prime of $ 0.245 with respect to those of the category “Trader”, and for each new out connection (out-degree) that an actor has, the Net Profits are increased by $ 0.068.

In the case of the regression model of the Net Unitary Profits, the categories that have a positive prime on this variable are again “Exporter” and “Artisanal Fishermen”, while “Fish Shops” engaged in “Meat” presentation has the lowest economic net unitary profit, with unit decreases of 0.270 and 0.821 respectively, compared to the reference categories. Actors with high out-closeness, as it is the case of traders in the last steps of the supply chain, have also a prime in the Net Unitary Profits.

4. Discussion

4.1. Artisanal fishermen

Bizarro et al. (2009) reported that in Baja California Sur the main shark species caught by the artisanal fishing fleet belong to the genera *Alopias, Carcharhinus, Isurus, Mustelus, Nasolamia, Rhizoprionodon, Sphyrna* and *Squatina* with price ranges ranging from $0.25 USD/Kg to $1.02 USD/Kg and identifying that the markets associated with sharks and their derived products are generally local markets in cities of Baja California and Baja California Sur (Ensenada, La Paz, Loreto, Los Cabos), although they also mention Mexico City and the United States of America. As well as in this study, the interviewees mentioned that the price ranges of shark and “dogfish” that are paid to fishermen for their products vary between $0.30 USD/Kg and $1.32 USD/Kg and in the same way they mentioned that among the main destinations are Mexico City, specifically the Mercado de La Nueva Viga, in addition to the Mercado del Mar in Zapopan, Jalisco, which stand out for registering the largest numbers of wholesalers in Mexico (Islas-Moreno, 2007), although they also have retail establishments.

Table 3
Relationship between the indices of Degree, betweenness and Proximity. (Taken and modified from Zhang and Luo (2017)).

	High Degree	High Betweenness	High Closeness
Low Degree		Crucial and supporting actors for network flow. Node #13	Individual connections with important or active actors. Nodes #35, #36, #37
Low Betweenness	It shows redundancy in the connections of the actors. Nodes #4, #17 and #19		There are many connections on the network, the actors are close to actors highly connected to others on the network. Nodes #5, #7 and #23
Low Closeness	The actors are part of groups that are far from the rest of the actors in the network. Nodes #2, #3, #4	Individuals hoard other nodes in the network. Nodes #2 and #3	

Table 4
Relationship of economic variables and network metrics with Net Profits and Net Unitary Profits.

	Net Profits	Net Unitary Profits
Variable	**Estimates (SE)**	**Estimates (SE)**
Quantity (Kg)	0.852 (0.072) ***	–
Meat Presentation	−0.792 (0.291) **	−0.821 (0.293) **
Exporter Type	1.054 (0.316) **	1.016 (0.318) **
Artisanal Fishermen Type	0.245 (0.097) *	0.234 (0.098) *
Fish Shop Type	–	−0.270 (0.128) *
Out-Degree	0.068 (0.029) *	–
Out-Closeness	–	2.29E+03 (1.29E+3).
$P < 0.1$	$\mathbf{R^2 = 0.7782}$	$\mathbf{R^2 = 0.7909}$

The values shown are the coefficients (standard error) of two multiple regression analyses by the stepwise variable selection method. The multiple determination coefficients ($\mathbf{R^2}$) of each regression model are shown with a significance level of $P < 0.1$. “***" indicate significance at level 0.001, "**" indicate significance at level 0.01, "*" indicate significance at level 0.05, and "." indicate significance of 0.1.

Regarding the topological metrics, many of the nodes that are in the category “Artisanal Fishermen” show the lowest estimates of the degree, closeness, betweenness, and eigen-centrality metrics, at the same time that they show the highest values of the constraint index. These results point to an isolated situation of these nodes in the commercial network, as well as trade restriction to a single buyer. These results agree with the conclusions of Crona et al. (2010) and Coronado et al. (2020), which point to the existence of exclusive agreements of artisanal fishermen with intermediaries or merchants, in a form of captive coordination of the former to bring their product to the market. The actors interviewed during this work indicated that shark fishery is usually the only job opportunity for them in their communities, so they could see the need to establish this type of agreement with traders in order to carry out their economic activity. These relationships of captive hoarding or coordination could also be examples of a monopsony model present in artisanal shark fishery in Mexico, where there is a single buyer or consumer of the products offered by some nodes belonging to the category of artisanal fishermen.

However, according to the regression results, the category of artisanal fishermen has a positive prime in both Net Profits and Net Unitary Profits with respect to the rest of categories excepting exporters. The reason of this outcome could be due to the fact that some of the actors (e.g., #78) in the artisanal fishermen category manage high volumes of shark product and has no competitors within the same category, so its position and ability to obtain profits improves. However, this is not the case of many other artisanal fishermen (e.g., #85, #87 and #89 to mention just a few), which are located in the same fishery area but any one sells small amount of product to a unique trader. The economic performance of their activity for these artisanal fishermen is low.

In Mexico, artisanal shark fishery is considered an important source of food, jobs and economic profits (Dorantes-González, 2017) and the commercialization of this resource occurs mainly at the national level (Castellanos-Betancourt et al., 2013). Then, from the findings above, it would be expected that policies favoring the coordination of producers, mainly through fishermen’s cooperatives societies, would have a great impact on the Net Profits and Net Unitary Profits.

4.2. *Traders*

The Mercado de La Nueva Viga stands out as the largest seafood marketer in Latin America and the second largest in the world, only passed by the Tsukiji market in Tokyo, Japan, since the products marketed in it represent 65% of the national fish production with trade amounting to approximately one million tons per year

(Ballesteros-Hernández et al., 2019). The Mercado del Mar is the second largest market of marine products in Mexico, in which 500 tons (t) to 1000 t of marine products per day are marketed (Pedroza-Gutiérrez, 2017).

At the national level, wholesale markets are the key players in the distribution of food, since they function as regional collectors and distributors, organizing producers, intermediaries, and other wholesalers to get the products to the final consumer (Pedroza-Gutiérrez, 2017). This demand for marine products generates incentives to increase catches, as well as to promote changes in the market structure and in the behavior of the fishing sector (Coronado et al., 2020).

The results confirm that traders are key players in the supply chain of shark products. Of the 94 nodes belonging to the commercial shark network, three nodes of the trader category stand out for showing the highest betweenness values (Table 3), so according to La Ola et al. (2020) and Hartley (2010), they are functioning as bridge nodes, responsible for the transmission of products between nodes or groups of nodes that are separated.

4.3. Exporters

The category of exporter (fin trade) turned out to have the highest positive coefficient in the Net Profits and the Net Unitary Profits with respect to the rest of categories. The high performance of exporters could be due to two factors: 1.- The high price that Mexican shark fins have in the international market, specifically in the Asian market (Castellanos-Betancourt et al., 2013), reaching prices ranging from $ 51.02 USD/Kg (Dorantes-González, 2017; FAO, 2021), and 2.- The position that the exporters have in the network (Fig. 1), connected to a unique fin collector close to the main trader and artisanal fishermen. In addition, this fin collector mentioned during the interviews that he is in charge of gathering, cleaning and drying the fins for sale, so the exporters only buy the product and transport them to the Asian market, so there are no processing costs, affording only export costs, the values of which we could not calculate. The high differences of the economic returns among this category and the previous traders point to the existence of the oligopsony capacity of exporters, although this has not been confirmed in this study due to sample restrictions.

Two topological characteristics of the supply network influence on the economic performance of the actors. They are the ability of the nodes to access other actors in the network and sell their product (out-degree) and to be located in the last steps of the value chain (out-closeness). We find that the nodes with the highest values of these two metrics (Table 2) are also among the most important actors for the betweenness and eigencentrality metrics, which would mean that they are connected to nodes highly connected with others and therefore, they have a high capacity to connect with the largest number of nodes in the network and can function as bridges for the transmission of products (Junker and Schreiber, 2008; Zhang and Luo, 2017; Wilson and MacDonald, 2018). This result agrees with the theory of structural holes (Burt, 1995; 2004), which highlight that the brokerage mechanism of this kind of nodes allows them more entrepreneurial opportunities and therefore obtain higher economic performance. The key role in the transmission of product can also be accompanied by high leadership capacity, influence and good reputation in the network (Zhang and Luo, 2017), an intangible value that may influence on the economic returns.

4.4. Limitations

This study is not absent of limitations. Specifically, our findings are based on the analysis of the flow and price of the product, disregarding other intangible factors influencing economic returns, such as personal relationships and information. Moreover, prices are not disaggregated by type of presentation, which is also a source of bias in the estimation.

One of the arguments to explain the low centrality values of many artisanal fishermen is the existence of captive coordination between this group and intermediaries. This captive coordination acts as a market failure, limiting the coordination capacity of producers. Although some of the interviewed fishermen point to the existence of this kind of relationship, a further analysis of this situation is out of the scope of this paper.

The study deals with a restricted sample, both spatially and temporally of the shark supply network in Mexico, so they cannot be directly extrapolated to other markets and may have seasonal patterns. Moreover, although information triangulation was done for some nodes, most of the information was provided by the interviewees and therefore is subject to possible imprecisions and mistakes.

5. Conclusions

This study provides one of the first views of the shark market from a weighted network analysis approach, taking into account economic variables, characteristics of the actors involved, indices of centrality of network analysis and the flow of products and monetary value within the system. We highlight the importance of analyzing the structure of social networks, as a tool to identify the dynamics of commercial networks, as well as the identification of key actors in the commercial system.

In the case study, we identified 94 nodes that integrate the shark market grouped into 6 categories, with some traders presenting the highest Net Profits and the exporters group presenting the highest Net Unitary Profits. Key actors in the shark trade network in Mexico were identified, for having characteristics that make them important to the system. The exporters trading fin were found to obtain a higher Net Unitary Profit, due mainly to the high price in the international market of this product. The findings reveal that most of artisanal fishermen obtain low economic performance due to the isolation position in the supply network and low market power derived from the exclusive agreement with intermediaries. Then, this empirical study validates the standard economic networks theory that argues that the monopolistic situation between producers and intermediaries favor the economics returns of the latter. Nevertheless, the results also reveal that this situation can revert if artisanal fishermen can trade large volumes of product, due among other reasons to the lower total production costs that this sector faces with respect to traders and the inexistence of competitors.

On the other hand, the number of buyers also determine the economic performance of the system. The results indicate that having a large variety of buyers increases the economic returns of the actors in the supply chain. Moreover, the position of the actors is also a relevant factor. In this regard, those actors located in the last steps of the supply chain obtain better returns than those located in the first or middle steps.

Some managerial implications can be extracted from these findings. The results reveal that actors having agreement with only one buyer leads them to have low share of the net profits in the value chain. Then, agents involved in the commercialization of shark should make efforts to diversify their potential buyers in order to increase profits. Moreover, the findings justify policies directed to favor the grouping and coordination of artisanal fishermen, since they can thereby compensate their disadvantaged position in the first steps of the chain by avoiding the negative effect in the profit distribution of having only one buyer and competition among themselves.

Declaration of competing interest

The authors declare that they have no known conflict financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2023.106680.

References

Asche, F., Bellemare, M.F., Roheim, C., Smith, M.D., Tveteras, S., 2015. Fair enough? Food security and the international trade of seafood. World Dev. (67), 151–160.
Ballesteros-Hernández, S., Del Moral-Flores, L.F., Sánchez-Cárdenas, R., 2019. Los tiburones y rayas comercializados en el mercado de La Nueva Viga, Ciudad de México: lista sistemática y estado de conservación. [Sharks and rays traded in the La Nueva Viga market, Mexico City: systematic list and state of conservation. Ciencia Pesquera 27 (1), 27–38.
Barnes, M.L., Lynham, J., Kalberg, K., Leung, P., 2016. Social networks and environmental outcomes. Proc. Natl. Acad. Sci. USA 113 (23), 6466–6471.
Bizarro, J.J., Smith, W.D., Hueter, R.E., Villavicencio-Garayzar, C.J., 2009. Activities and cath cmposition of artisanal elasmobranch fishing sites on the eastern coast of Baja California Sur, méxico. Bull. South Calif. Acad. Sci. 108 (3), 137–151.
Burt, R.S., 1995. Structural Holes: the Social Structure of Competition. Harvard university press.
Burt, R.S., 2004. Structural holes and good ideas. Am. J. Sociol. 110 (2), 349–399.
Castellanos-Betancourt, J.C., Ramirez-Santiago, C.E., Castillo-Géniz, J.L., 2013. Catálogo de aletas, tronchos y cabezas de tiburones en el Pacífico Mexicano [Catalog of shark fins, trunks and heads in the Mexican Pacific]. SAGARPA, p. 61.
Clark, C.W., 2010. Mathematical Bioeconomics: the Mathematics of Conservation. John Wiley & Sons.
Coronado, E., Salas, S., Cepeda-González, M.F., Chuenpagdee, R., 2020. Who's who in the value chain for the Mexican octopus fishery: mapping the production chain. Mar. Pol. (118), 1–13.
Crona, B., Nyström, M., Folke, C., Jiddawi, N., 2010. Middlmen, a critical social-ecological link in coastal communities on Kenya and Zanzibar. Mar. Pol. (34), 761–771.
Cruz, E. F., da Cruz, A.M.R., & Gomes, R. Analysis of a traceability and Quality monitoring platform for the fishery and aquaculture value chain. 14th Iberian Conference on Information Systems and Technologies (CISTI). 1-6.
Csardi, G., Nepusz, T., 2006. The igraph software package for complex network research. InterJournal. Complex Systems. Disponible en: http://igraph.org.
Dent, F., Clarke, S., 2015. State of the Global Market for Shark Products. FAO, Roma, p. 187. FAO Fisheries an Aquaculture Technical paper No. 590.
Dorantes-González, M.A., 2017. Tendencias de captura y caracterización del mercado de tiburón en el sur del Golfo de México y Caribe Mexicano. Tesis de Maestría. [Capture trends and characterization of the shark market in the southern Gulf of Mexico and the Mexican Caribbean. Master's Thesis]. México, p. 78.
Drury, O.E., Crona, B., 2017. Assistance networks in seafood trade – a means to assess Profit distribution in small-scale fisheries. Mar. Pol. (78), 196–205.
Easley, D., Kleinberg, J., 2010. Networks, Crowds, and Markets: Reasoning about a Highly Connected World. Cambridge university press.
Everett, M.G., Bogartti, S.P., 2020. Unpacking Burt's constraint measure. Soc. Network. (62), 50–57.
FAO, 2021. Global fish trade and processed products statistics. Disponible en. https://www.fao.org/fishery/statistics/global-commodities-production/en. Consultado el 8 de Junio de 2021.
Ferretti, F., Jacoby, D.M.P., Pfleger, M.O., White, T.D., Dent, F., Micheli, F., Rosenberg, A.A., Crowder, L.B., Block, B.A., 2020. Shark fin trade bans and sustainable shark fisheries. Conservation Letters 13 (3), 12708.
García-Núñez, N.E., 2008. Tiburones: Conservación, Pesca Y Comercio Internacional [Sharks: Conservation, Fisheries and International Trade]. Edición bilingüe. Ministerio de Medio Ambiente, y Medio Rural y Marino Madrid, p. 117.
Gephart, J.A., Pace, M.L., 2015. Structure and evolution of the global seafood trade network. Environ. Res. Lett. 10 (12), 125014.
Goldstein, R., Vitevitch, M.S., 2017. The influence of closeness centrality on lexical processind. Front. Psychol. 8, 1–9.
Gómez, S., 2019. Centrality in networks: finding the most important nodes. In: Moscato, P., y de Vries, N. (Eds.), Business and Consumer Analytics: New Ideas. Springer, Cham, pp. 401–433.
González-Mon, B., Bodin, O., Crona, B., Nenadovic, M., Basurto, X., 2019. Small-scale fish buyers' trade networks reveal diverse actor types and differential adaptative capacities. Ecol. Econ. (164), 106338
Hartley, T.W., 2010. Fishery management as a governance network: examples from the Gulf of Maine and the potential for communication network analysis research in fisheries. Mar. Pol. (34), 1060–1067.
Hernández-Guerra, J.M., Pedroza-Gutiérrez, C., 2016. The Influence of the Network Topology on the Agility of a Supply Chain, 10094. ArXiv, abs/1611.
INAPESCA, 2006. Sustentabilidad y Pesca Responsable en México. Evaluación y Manejo [Sustainability and Responsible Fishing in Mexico. Evaluation and Management]. México, p. 544.
Islas-Moreno, J.A., 2007. Mejoramiento de los Mercados Internos de Productos Pesqueros en América Latina y el Caribe [Improvement of Internal Markets for Fishery Products in Latin America and the Caribbean]. INFOPESCA. Proyecto TCP/RLA/3111.
Jenkins-Smith, H.C., Ripberger, J.T., Copeland, G.W., Nowlin, M.C., Hughes, T., Fister, A. L., Wehde, W., 2017. Quantitative Research Methods for Political Science, Public Policy, and Public Administration: with Applications in R. University of Oklahma, Oklahoma.
Jenssen, J.I., Greve, A., 2002. Does the degree of redundancy in social networks influence the success of business start-ups? Int. J. Entrepreneurial Behav. Res. 8 (5), 254–267.
Jiménez-Sánchez, J.E., 2002. Marco conceptual de la cadena de suministro: un nuevo enfoque logístico [Supply chain conceptual framework: a new logistics approach]. Secretaría de Comunicaciones y Transporte. México. 248.
Junker, B.H., Schreiber, F., 2008. Analysis of Biological Networks. John Wiley & Sons, p. 346.
Kimani, P., Wamukota, A., Manyala, J.O., Mlewa, C.M., 2020. Factors influencing financial performance in marine small-scale fisheries values chain in Kenya. Mar. Pol. (122).
La Ola, T., Wianti, N.I., Tadjuddah, M., Suriana, Buana, T., Rosmawaty, Abdullah, S., Wunawarsih, I.A., 2020. Social network Analysis: key actors of cooperation between Sama Bajo and land-dwellers in Wakatobi marine national park. IOP Conf. Ser. Earth Environ. Sci. 441.
Packer, H., Schmidt, J., Bailey, M., 2020. Social networks and seafood sustainability governance: exploring the relationship between social capital and the performance of fishery improvement projects. People and Nature (2), 797–810.
Pedroza-Gutiérrez, C., 2017. El Mercado del Mar (Guadalajara, México): un mercado con imagen [El Mercado del Mar (Guadalajara, Mexico): a market with an image]. Distribución y Consumo (3), 74–78.
Purcell, S.W., Crona, B.I., Lalavanua, W., Eriksson, H., 2017. Distribution of economic returns in small-scale fisheries for international markets: a value-chain analysis. Mar. Pol. (86), 9–16.
R Core Team, 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
Ramírez-Sánchez, S., Pinkerton, E., 2009. The impact of resource scarcity on bonding and bridging social capital: the case of Fisher's information-sharing networks in Loreto, BCS, Mexico. Ecol. Soc. 14 (1), 22.
Rosales, R.M., Pomeroy, R., Calabio, I.J., Batong, M., Cedo, K., Escara, N., Facunla, V., Gulayan, A., Narvadez, M., Sarahadil, M., y Sobrevega, M.A., 2017. Value chain analysis and small-scale fisheries management. Mar. Pol. (83), 11–21.
Sagarpa, 2017. Auario Estadístico de Acuacultura y Pesca de la Comisión Nacional de Acuacultura y Pesca [Statistical Yearbook of Aquaculture and Fisheries of the National Aquaculture and Fisheries Commission]. México, p. 293.
Shea, K.H., To, A.W.L., 2017. From boat to bowl: patterns and dynamics of shark fin trade in Hong Kong – implications for monitoring and management. Mar. Pol. (81), 330–339.
Saldaña-Ruíz, L.E., Sosa-Nisjizaki, O., Cartamil, D., 2017. Historical recontruction of Gulf of California shark fishery landings and species composition, 1939-2014, in a data-poor fishery context. Fish. Res. (195), 116–129.
Sexton, R.J., Zhang, M., 2001. An assessment of the impact of food industry market power on US consumers. Agribusiness 17 (1), 59–79.
Smith, M.D., Roheim, C.A., Crowder, L.B., Halpen, B.S., Turnipseed, M., Anderson, J.L., Asche, F., Bourillón, L., Guttormsen, A.T., Khan, A., Liguori, L.A., McNevin, A., O'Connor, M.I., Squires, D., Tyedmers, P., Brownstein, C., Carden, K., Klinger, D.H., Sagarin, R., Selkoe, K.A., 2010. Sustainability and global seafood. Science 327 (5967), 784–786. https://doi.org/10.1126/science.1185345.
Van Houtan, K.S., Gagné, T.O., Reygondeau, G., Tanaka, K.R., Palumbi, S.R., Jorgensen, S.J., 2020. Coastal sharks supply the global shark fin trade. Biol. Lett. 16, 20200609.
Venables, W.N., Ripley, B.B., 2002. Modern Applied Statistics with S, fourth ed. Springer, New York. 0-387-95457-0.
Vidal-Hernández, L., Canto-Lugo, E., Carmona-Escalante, A., Huerta-Quintanilla, R., Garza-Lagler, C., López-Rocha, J., 2019. Properties, communities and robustness in the Yucatan sea cucumber trade network. Ocean Coast Manag. 168, 226–237.
Watson, R.A., Green, B.S., Tracery, S.R., Farmery, A., Pticher, T.J., 2016. Provenance of global seafood. Fish Fish. 17, 585–595. https://doi.org/10.1111/faf.12129.
Wilson, L., MacDonald, B.H., 2018. Characterizing bridger organizations and their roles in a coastal resource management network. Ocean Coast Manag. 153, 59–69.
Wooldridge, J.M., 2013. Introductory Econometrics: A Modern Approach, fifth ed. South-Western, Mason, OH, USA.

Zeileis, A., Hothorn, T., 2002. Diagnostic checking in regression relationships. E News 2 (3), 7–10.
Zepeda-Domínguez, J.A., Zetina-Rejón, M.J., Espinoza-Tenorio, A., Ponce-Díaz, G., Lluch-Belda, D., Espinosa-Romero, M.J., Torre-Cosío, J., Cisneros-Mata, M.A., 2015. Mapeo topológico de los actores involucrados en el manejo de la pesquería de jaiba café Callinectes bellicosus en Sonora, México [Topological mapping of the actors involved in the management of the brown crab Callinectes bellicosus fishery in Sonora, Mexico]. Ciencia Pesquera 23, 81–90.
Zhang, J., Luo, Y., 2017. Degree centrality, Betweenness centrality, and Closeness centrality in social network. Advances in Intelligent Systems Research 132, 300–303.