RESEARCH

Knowledge transfer networks on COVID-19 in aquaculture organizations of the Northern Pacific Region of Mexico

Redes de transferencia del conocimiento COVID-19 en organizaciones acuícolas del pacífico norte de México

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Abstract

The objective of this study was to analize the knowledge transfer networks on COVID-19 in shrimp aquaculture production groups in the northern Pacific region of Mexico. Method. A cross-sectional, descriptive and correlational study was carried out, which allowed acquiring information from a survey of 102 aquaculture producers in the northern Pacific region of the state of Sinaloa. Social Network Analysis (SNA) was used for the analysis of results. Results. Four sources of information are reported - Health Sector, Private Sources, Governmental Sector and Media - to which the producers turn to acquire information on Covid-19 and its effects on the aquaculture activity.

Key words: Social Network Analysis (SNA) - Knowledge Transfer Networks - COVID-19 - Aquaculture Organizations

JEL code: Z13, D83, D2

Resumen

El presente trabajo tuvo como objetivo analizar las redes de transferencia del conocimiento sobre el COVID-19, en los conjuntos acuícolas productores de camarón de la región pacifico norte de México. Método. Se realizó un estudio de corte transversal, descriptivo y correlacional, el cual permitió adquirir información de una encuesta de 102 acuacultores de la región del pacifico norte, del estado de Sinaloa. Para el análisis de resultados se probó el Análisis de Redes Sociales (ARS). Resultados. Se reportan 4 fuentes de información -Sector Salud, Fuentes Privadas, Sector Gubernamental y Medios de Comunicación- a las cuales los productores acuden para adquirir información sobre el Covid-19 y sus efectos en la actividad acuícola.

Palabras clave: Análisis de Redes Sociales (ARS) - Redes de Transferencia de conocimiento - COVID-19 - Organizaciones Acuícolas.

Código JEL: Z13, D83, D2

1. Introduction

The disease known as Coronavirus disease 2019 (COVID-19) spread rapidly throughout communities worldwide, affecting over 6.7 million people due to the Sars-Cov-2/COVID-19 pandemic (Silva-Sobrinho et al., 2021). The various interconnections of the Coronavirus pandemic led to the collapse of the global capitalist economy—or at least

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triggered an unprecedented recession and potential depression not seen since World War II (Waitzkin, 2021). Public health policies, as governmental tactics, were based on social isolation, social segregation, and the limitation of work-related activities. This economic impact of COVID-19 affected all activities performed by human capital.

Under the adverse conditions brought about especially by COVID-19, companies and entrepreneurs faced complex decision-making and had to rapidly adapt to the use and management of technology and innovation. León, López, & Sandoval (2009) highlight the importance of managing technical knowledge through business networks or the interconnectivity among different entities that provide information—such as research centers, universities, competitors, suppliers, and others—who contribute valuable resources like knowledge and information spillovers to organizations. Similarly, academic producers of scientific-technological knowledge form external networks to transmit this intangible resource—knowledge—to society (Carrazco & León, 2017; Vázquez, 2017).

Knowledge transfer networks among agents/actors are key to generating valuable resources within their areas of specialization. These transfer methods can create innovations that are promoted within knowledge networks or sub-networks composed of different branches or innovation nodes (Arias & Aristizábal, 2011; Vázquez, 2017). In the knowledge era, the capacity to generate valua ble knowledge primarily stems from universities, research centers, government institutions, and productive sectors. These actors play an important role in the scientific and technological development of companies and in both regional and local economic and social development (León, Gutiérrez & Carrazco, 2019). Like other productive activities, aquaculture is affected by internal and external factors that influence decision-making, reduce productivity, and consequently, impact profitability and competitive positioning (Araiza et al., 2020).

This research identified a set of institutional agents, both public and private, whose purpose is to meet the demands and needs of the shrimp aquaculture sector by generating, transferring, and communicating knowledge throughout production processes during the coronavirus pandemic. For this study, we identified four main sources of information (health, media, individuals, and government institutions). The objective of this study was to compare COVID-19 knowledge networks within shrimp-producing organizations in the Northwestern region of Mexico.

Based on the above, the following research question is posed:

What are the knowledge networks related to COVID-19 among shrimp aquaculture groups in the northern Pacific region of Mexico, particularly in the state of Sinaloa?

This article is structured as follows. The first section presents a literature review on the importance of scientific-technological knowledge transfer networks. The second section addresses the methodological procedure, and the analytical framework used in our analysis. The third section presents the results and discussion. The fourth section contains the conclusions of the research. Finally, the references that supported the work are listed.

2. Literature review

2.1. Knowledge Transfer Networks (KTN)

The study of knowledge and innovation transfer networks is considered a source of competitive advantage for companies, as it increases the stock of valuable knowledge that drives the creation of value through the transformation of manufactured goods and services. Thus, technology transfer consolidates innovation and serves as an important channel for cohesion among scientific-technological actors, universities/academics, the government sector, suppliers, and competitors.

Bergman (2009) notes that studies on knowledge and innovation transfer networks are not new. However, they emphasize the relevance for companies of managing technological innovation networks to support knowledge growth and development, helping improve competitive positioning in increasingly dynamic and turbulent local and international markets. In this sense, innovations can arise through complex social interactions among a group of actors committed to generating and transferring knowledge within the network (Hermans et al., 2017). Social networks act as catalysts in learning mechanisms to mitigate problems and foster new ideas. Clearly, in business innovation, social networks are indispensable as effective tools for research and for transforming commercial products and services offered to local and international markets (Kolleck, 2013).

Pérez & Harwith (2008) argue that networks with greater link capacity exhibit higher average rates of adoption for profitable knowledge. This is crucial for companies, as contact networks facilitate access to information and the ability to transform knowledge into service improvements. Furthermore, the strategic positioning and quality of actors within the network allow them to acquire key information from external sources, thereby boosting productivity and competitiveness (Aguilar et al., 2016). Strong and direct business relationships help establish a favorable position relative to competitors. In other words, strategic positioning within a knowledge transfer network acts as a source of competitive advantage for the company (Galán, Casanueva & Castro-Abancéns, 2010).

2.2. Social Network Analysis (SNA) as an approach to business studies

The RS is based on the study of the impact of multiple interactions among heterogeneous and homogeneous agents by classifying their structures. Structural analysis of social networks studies the behavior of individuals at the micro level (network structure), at the macro level, and the interaction between the two levels (Sanz, 2003). That is, ARS supports the analysis of interactions among individuals and organizations within the social network, reflecting both the quantity and quality of knowledge and information flows. León, Gutiérrez & Carrazco (2019) point out that ARS, as a social approach, addresses various aspects where data richness is a relevant factor, along with the variables or characteristics of the unit of analysis, based on questions such as: Who do you learn from and/or consult to acquire technical and productive knowledge related to your production unit? Additionally, ARS establishes a fundamental principle: Who are your contacts/relationships or immediate neighbors?

In this way, ARS holds a relevant position in studying organizational impacts and innovation networks, making it a suitable analysis method for these fields. However, innovation networks or collaborative networks among actors help facilitate the development of new products; though, they do not guarantee productivity and successful growth (Van der Valk & Gijsbers, 2010; Van der Valk, Chappin & Gijsbers, 2011; Landsperger & Spieth, 2011).

Thus, ARS facilitates the analysis of interactions between actors and their social and institutional environment. In this study involving agricultural producers (aquaculturists), measures of Degree, Betweenness, Authority, and Hub were used. According to social network theory and analysis (SNA theory), these indicators allow identifying reciprocal and non-reciprocal ties, which acknowledge that knowledge and information are transferred along these links.

Leyva, Borbón & Pérez (2018) point out that the structure formed by a set of companies within the same homogeneous sector and distributed within the same geographic area or locality results in a virtuous collaboration network. In ARS, actors in a social network may have different roles depending on their degree, highlighting their power of betweenness in relation to others and their closeness. Betweenness plays a key role for network members, as they benefit from the spillover of information arising from the interconnectivity of groups, thus gaining a more advantageous position due to their specific placement in the network.

Meanwhile, Pérez, Ureña & Rodríguez (2015) define betweenness degree as the extent to which other actors must pass through a focal actor to communicate with the rest of the actors. This metric provides an idea of the control each actor holds over relational flows within the network. Núñez-Espinoza, Figueroa-Rodríguez & Jiménez-Sánchez (2014) state that betweenness is the centrality measure indicating how frequently a node appears as a potential connection between otherwise disconnected nodes. These authors suggest that through betweenness in the network, actors connected to a group of actors through linking mechanisms positively influence either the opening or closure of cohesion processes in the social network or community (Colina et al., 2013).

For social network analysis, the position of edges can be studied through centrality measures. That is, the node with the highest number of links within the network has a greater capacity to absorb learning and innovation from participation with other actors who provide a spillover of valuable knowledge or control key information (Reinholt, Pedersen & Foss, 2011).

Table 1. Metrics of social netowork analysis

Concept	Definition	Authors
Degree	a) The number of actors to which an actor is directly connected. b) The number of adjacent nodes. c) It expresses the percentage of ties an actor has. The higher the degree, the greater the number of people a node connects with, thus representing the quantity of links but not their quality. d) Degree is a simple centrality measure that counts how may neighbors a node has.	Borgatti et al. (2002); Sanz (2003).
Betweenness	a) The position of a node in the network in terms of its capacity to connect pairs of nodes in the network, "it is the sum of the combinations of all pairs of nodes in the network that communicate via the shortest path". b) The ability of a node to mediate communication between pairs of nodes. These nodes are also known as bridge actors. c) This indicator measures the extent to which a point is located between other points in the network. "Its importance lies in measuring the capacity of nodes to connect different groups and act as intermediaries, and they are usually associated with individuals who have greater innovation capability".	Freeman et al. (1991)
Authority	a) A node that provides relevant content in a network and selects, groups, and disseminates information within the network. b) Provides a measure of how valuable the information provided by a node is to its linked actors; calculated using the PageRank algorithm, which computes the authority of node i based on the authority of its neighbors according to their relationships.	Marcelino, Pinto & Marqués (2020); De la Rosa et al. (2005).
Hub	a) An actor/node that concentrates the largest number of links in the network, "dynamically managing organizational boundaries by connecting external resources with those inside". b) The capacity of a hub is measured by the maximum incoming or outgoing information per period, assessing the quality and quantity of the information (it is a space where diverse actors interact).	Cruz (2014); Roldán-Suárez et al. (2018).

Source: Own elaboration.

Marcelino, Pinto & Marqués (2020) determine that authority in a social network is considered a node that provides valuable information to actors interconnected in diverse ways with others. De la Rosa et al. (2005) identify authority in social network analysis as the node author with the highest hierarchy concerning the edges forming the graph. Building effective and efficient authority networks is associated with the mediating role played by the best-positioned actor in the network, acting as a bridge or direct link to social capital to exploit their skills, information exchange, accessibility, and connections with other actors (Yeniterzi & Callan, 2014).

Hubbell (1965), Kleinberg (1999), and Arcos (2017) clearly explain the relevance of authority distribution by measuring how valuable the information of an actor is to its linked nodes, whereas the Hub measures the quality of the nodes connected to the actor with the highest authority. Hubbell (1965) explains that each node has a priori internal weight from the beginning, accompanied by the strength of connection between each pair of nodes. The interaction of diverse actors through a similar notion of influence weights, scaled by connection strength, captures its most prominent and central members with a large volume of information in a more manageable representation. In other words, the hub maintains value with environmental agents and acts as a key information source for the organization. Therefore, the quantity and quality of interconnectivity among actors determine the level of technological and competitive innovation compared to competitors.

According to social network analysis, Roldán-Suárez et al. (2018) argue that the Hub increases the content and type of knowledge flows in the network, promoting improvement of relational capital and the structure of regional networks. Arias and Alarcón (2019) maintain that agri-food innovation systems feedback knowledge to achieve technological change with collective benefits and must possess synergies between actors and productive systems, where relational capital seeds ties intraorganizationally and extraorganizationally, in regions that form Hubs based on their diversity of relations and closeness in the network with other actors.

3. Methodology

3.1. Participants

This study was conducted using a quantitative approach based on ARS. A sample was taken consisting of aquaculture farms located in the northwestern region (Sinaloa) of Mexico, during the period from April to August 2020. According to Leskovec & Faloutsos (2006), the type of sampling used in ARS differs from conventional analysis and can be done in three ways: a) random selection of nodes, b) random selection of links, and c) an exploration technique that simulates random steps. For this study, the first type was used, as it establishes a sub-network that represents the total connections of the original network (León et al., 2019).

3.2. Sample characteristics

This study is presented as a cross-sectional, descriptive, and correlational study (Field, 2013), with a randomly selected total of 102 shrimp-producing aquaculture units along the Sinaloa coast. Of these, 79.1% (n=81) were male and 20.9% (n=21) were female. The aquaculture producers surveyed were between 29 and 58 years old. Their educational background showed that 73.5% had completed university studies, 10.7% had finished upper secondary education (high school), and 15.6% had a technical degree.

According to the statistical description, the sample consisted mainly of small enterprises (74.50%), followed by medium-sized ones (23.52%), and to a lesser extent, large enterprises, which accounted for only 1.96%. Additionally, it was reported that some aquaculture units had an average operational history of 10 years (50%), followed by those with 11–15 years of operation, which represented 19.60% of the sample. Enterprises with 16–20 years of experience accounted for 8.82%, and those operating for over 20 years represented 21.56%. Regarding the economic sector (social or private) to which these aquaculture units belong, 94.11% were in the private sector, and 5.88% were in the social sector. The human experience of aquaculture producers in this region showed that 50% of respondents were aged between 39 and 50 years. A portion of the population reported being between 29 and 40 years old, representing 26.47%, while a group aged over 51 years made up 23.52%, where their experience in the field is key for future generations of aquaculture producers in Sinaloa.

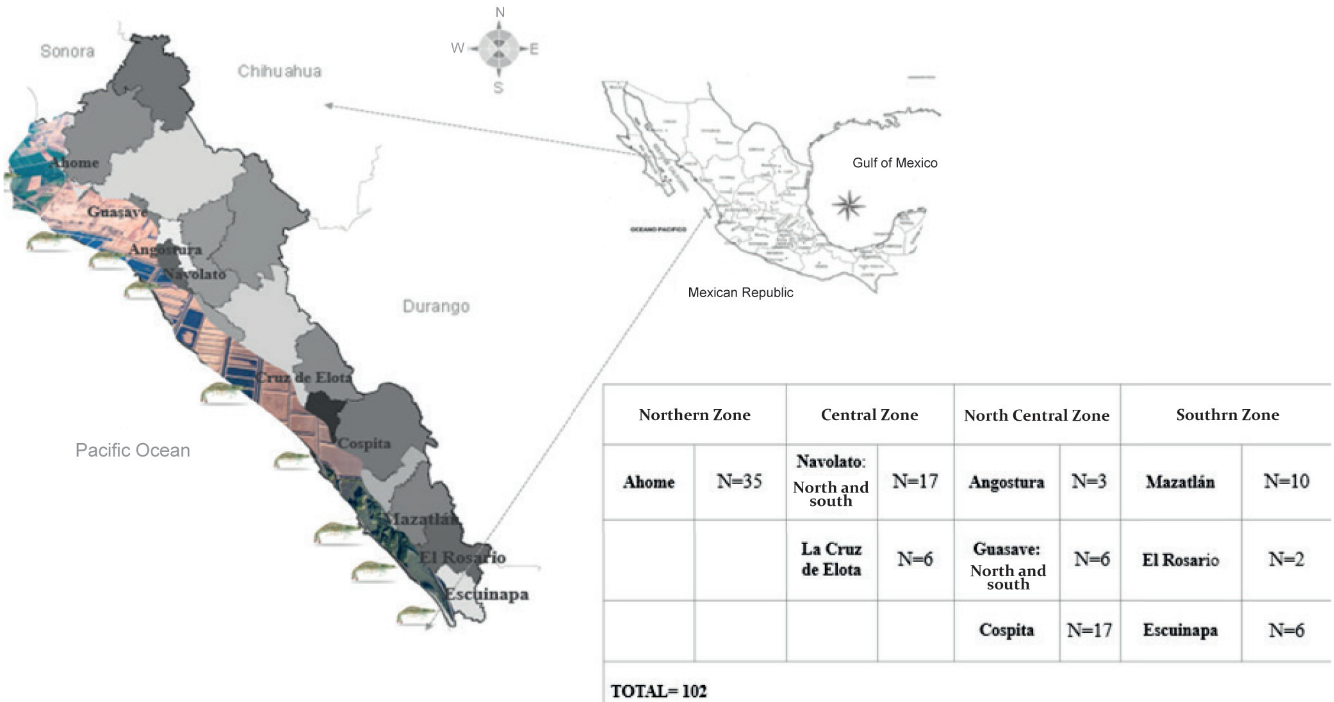
3.3. Research context

According to the regional diagnosis and planning for fisheries and aquaculture in Mexico, the Secretariat of Livestock and Rural Development (SADER) states that Region 1 of the northern Pacific, where the State of Sinaloa is located, is considered a significant corridor in the agri-food industry through shrimp production by aquaculture (SAGARPA, 2008). Geographically, Image 1 illustrates the regions that provided valuable information on knowledge networks during COVID-19 times.

3.4. Instruments

A questionnaire divided into three sections was applied: a) organizational variables; including company age, company size, and sector affiliation; b) productive variables related to COVID-19: including items about production before and during the pandemic, and the effects of COVID-19 on the production processes; and, c) social network variable: where organizations listed the contacts they turned to for information about COVID-19 and its relationship with the productive sector (see table 2).

Image 1. Location of the aquaculture units in Sinaloa.



Northern Zone		Central Zone		North Central Zone		Southrn Zone	
Ahome	N=35	**Navolato:** North and south	N=17	**Angostura**	N=3	**Mazatlán**	N=10
		La Cruz de Elota	N=6	**Guasave:** North and south	N=6	**El Rosario**	N=2
				Cospita	N=17	**Escuinapa**	N=6

TOTAL= 102

Source: Own elaboration.

Table 2. Instrument structure

Variable	Item
Organizational	a. Company size; b. Years in operation; c. Education level of the aquaculture producer (decision-maker); d. Age; e. Sector to which the farm belongs
Productive (COVID-19)	a. Production before COVID-19 (Kgs); b. Production during COVID; c. Was production affected by COVID-19?, d. Were biosafety measures increased?, e. Is there a plan to mitigate a prolonged COVID-19 outbreak?
Social Network	Provide a list of your main contacts whom you reached out to for information during COVID-19 contingency, in order to protect your employees and act responsibly under good practices.

Source: Own elaboration.

It is important to mention that the social network variable is visualized through a graph, and the following measures were considered:

- Degree: This measure is expressed by the following formula:

$$CD\ (ni)=jxij$$

- Betweenness: This is represented by the following formula:

$$CB\ (ni)=j<kgjk(ni)/gjk$$

Where gjk is the number of shortest paths from node j to node k, y gjik is the shortest path from j to k that passes through node i.

- Authority: This measure is expressed as:

$$ai=jB(i)hj$$

Where ai represents the authority of node i, and B(i) is the set of reference nodes foor node i.

- Hub: Represented by the following expression:

$$hi=jF(i)aj$$

Where hi represents the Hub weight of node i, and F(i) is the set of nodes referenced by node i.

3.5. Data Analysis

Data analysis was conducted using the statistical software STATA 14 for descriptive statistics. Meanwhile, for the construction of the networks (graph) and the calculation of network indicators (degree, betweenness, authority, and hub), the software Gephi 0.9.2 was used.

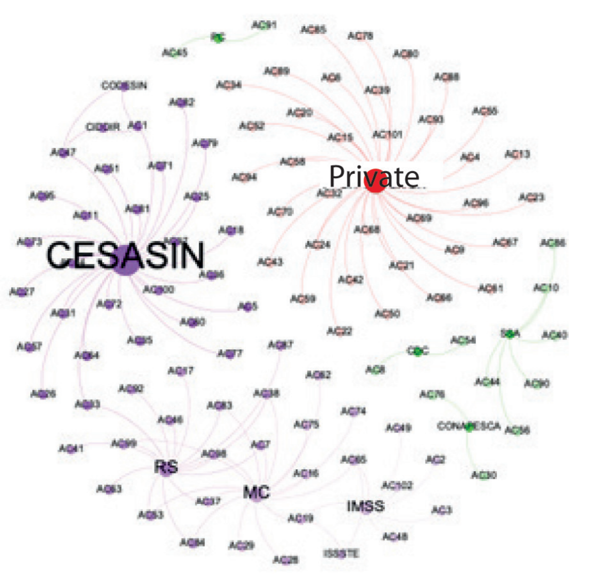
4. Results

4.1. Characteristics of the COVID-19 Knowledge Transfer Networks in aquaculture clusters in the state of Sinaloa

Based on a sample of 102 aquaculture clusters (farms) engaged in shrimp farming, four main sources were identified: 1. Health Sector, 2. Private Sources 3. Government Sector; and, 4. Media, to which producers turned for information about COVID-19 and its effects on shrimp farming in the northern Pacific region. Figure 1 shows a graphical representation of these sources as factors in the COVID-19 knowledge transfer process, in relation to the different sets of information sources linked to aquaculture farms.

The graph reveals that the sectors with the greatest weight in the network are the Health Sector (CESASIN, IMSS, ISSSTE, and SSA) and the Private Sector. Regarding the Health Sector, its significant impact on the aquaculture industry is understandable, as it encompasses the main official sources of health information. This finding aligns with Mohamad et al. (2020), who found that in Malaysia, the primary source of information for the population was the Ministry of Health, with 95% acceptance. On the other hand, the Private Sector is somewhat ambiguous, as the sources of information may include healthcare professionals but also individuals unrelated to the field, potentially leading to misinformation. This concern is also raised by Salaverría et al. (2020).

Figure 1. COVID-19 RTC in aquaculture farms of Sinaloa.



Source: Own elaboration
Note: The nodes starting with AC represent the aquaculture farms.

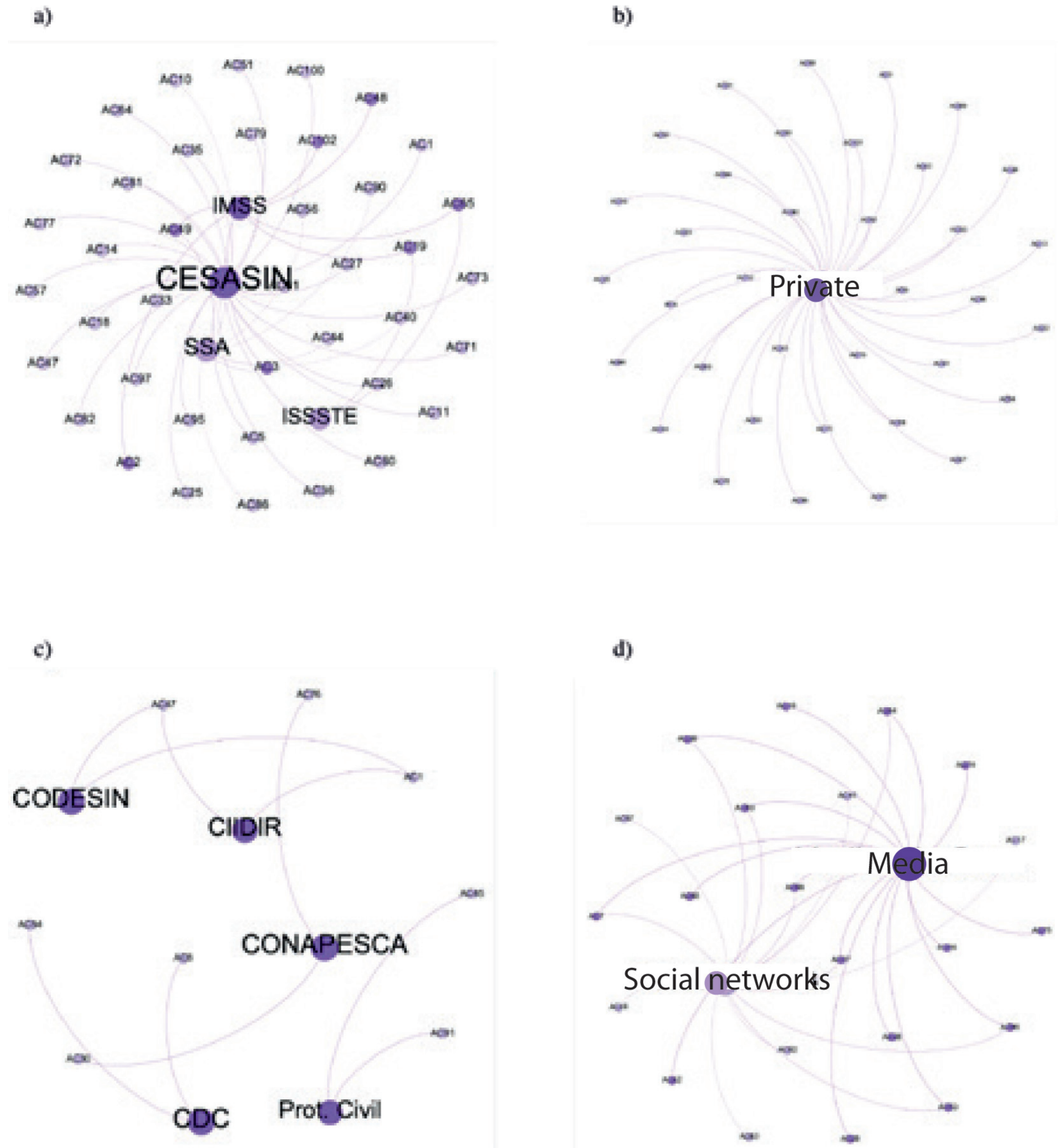
Figure 2 groups the network of the Health Sector. It shows that the network is highly centralized around CESASIN, which functions as the main source of knowledge transfer from the health sector to aquaculture enterprises. Secondary sources include IMSS, SSA, and ISSSTE. The number of aquaculture clusters belonging to this network is 40, and within it, 44 connections are generated. This network concentrates 39.2% of the aquaculture farms that make up the sample.

The figure also shows the links between aquaculture farms and private actors who provided information about COVID-19. Private sources refer to independent biologists, family members, friends, and other aquaculture producers in the studied region. The network is completely centralized, as the sources mentioned are grouped into a single node. Similar to Wang et al. (2020), personal networks played a significant role, with 46.1% of participants stating they turned to private sources for COVID-19 information.

In Table 3, the measures of the network presented in Figure 3a are shown. It can be observed that CESASIN is the main source of information within the Health sector, concentrating 27 links with producers (aquaculture farmers), making it the main actor acting as an intermediary (351.0) for the rest of the aquaculture farmers in the network. Regarding the authority measure, CESASIN provides highly valuable information to its linked actors (0.981); however, the nodes surrounding CESASIN do not provide high-quality information (0.188). This is natural since CESASIN, as the main actor within the network, concentrates the greatest information transfer, which represents higher quality. These results are consistent with those of Carrazco, Leyva, and León (2020), where the Sinaloa Aquaculture Cluster showed similar levels of intermediation (114.85), authority (0.29), and hub (0.15), considering CESASIN as a common denominator in the knowledge networks of both studies.

Table 4 presents the characteristics of the network shown in Figure 3b. This table highlights the value of influence and information quality provided by private sources. The intermediation of this node (Private) is high, as it is the only node that connects the rest of the network, with a value of 630.0. Likewise, the information it manages for the network members is highly valuable (0.986).

Figure 2. COVID-19 RTC in aquaculture clusters of Sinaloa.



Note: The nodes that start with AC are aquaculture farms.

Table 3. Measures of the Knowledge Network between Aquaculture Groups and the Health Sector

Actors	Degree	Betweenness	Authority	Hub
**CESASIN*	27	351.0	0.981	0.188
***IMSS*	7	67.0	0.0	0.0
****ISSSTE*	2	0.5	0.0	0.0
*****SSA*	8	69.5	0.0	0.0
Aquaculture average	1.1	1.55	0.02	0.12

Source: Own elaboration
*CESASIN. Comité Estatal de Sanidad Acuícola de Sinaloa
**IMSS. Instituto Mexicano del Seguro Social
***ISSSTE. Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado
****SSA. Secretaría de Salud

Table 4. Network Measures between Aquaculture Groups and Private Sources

Actors	Degree	Betweenness	Authority	Hub
Private	36	630.0	0.986	0.164
Aquaculture average	1	0.0	0.027	0.164

Source: Own elaboration.

Figure 3 shows the network between farms and the government sector. Unlike the previous networks, this one has only 13 actors, but is more distributed. However, it can be inferred that producers consulted the government sector to a lesser extent for COVID-19 information. In Thomas et al. (2021), there were no similar participation patterns to those in the present study; however, the government ranked the lowest (31%) among the sources consulted by the Australian population, similar to the knowledge network of the government sector regarding aquaculture farms.

Although all government actors have a degree of 2, CONAPESCA, CDC, and Protección Civil have higher intermediation (1) because they act as the only links between two aquaculture producers, hence their higher intermediation. On the other hand, CIIDIR and CODESIN have an intermediation of 0.5, as they share the same four aquaculture farms, which divides the connection. However, in terms of authority and hub, the latter two score 0.5 in both measures, as the information they transfer to these four farms is more influential (see Table 5).

Table 5. Network measures between aquaculture groups and the government sector

Actors	Degree	Betweenness	Authority	Hub
**CONAPESCA*	2	1	0.0	0.0
***CIIDIR*	2	0.5	0.5	0.5
***CODESIN	2	0.5	0.5	0.5
*****CDC*	2	1	0.0	0.0
Prot. Civil	2	1	0.0	0.0
Aquaculture average	1.25	0.12	0.12	0.12

Source: Own elaboration.
*CONAPESCA. Comisión Nacional de Acuacultura y Pesca.
**CIIDIR. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional. Unidad Sinaloa.
***CODESIN. Consejo para el Desarrollo Económico de Sinaloa.
****CDC. Centros para el Control y la Prevención de Enfermedades.

The knowledge network in Figure 3d represents the relationship between farms and the media. This is a bifurcated network between social media (SM) and traditional media (TM). What stands out in this network is that aquaculture producers largely alternated between both sources.

Both TM and SM have very similar measures, as reflected in the values in Table 6. However, TM has slightly higher values, as it connects with 16 aquaculture farms, has an intermediation of 162, and provides highly valuable information (0.714). In contrast, SM has an intermediation of 131, an authority score of 0.630, and a hub score of 0.201. Despite appearing to be a polarized network, it is actually very homogeneous, as there are eight aquaculture producers who are interconnected with both types of sources. It is important to note that this network ranks third in terms of degree, just six nodes below the private network. This shows that the media and social networks play a very important role within aquaculture farms. This result aligns with various studies showing that, globally, social media (internet) was the predominant source of information among the population (Wang et al., 2020; Mohamad et al., 2020; Aweke et al., 2020); however, these are also the sources most prone to misinformation and fake news (Salaverría et al., 2020).

Table 6. Network Measures between Aquaculture Groups and Media

Actors	Degree	Betweenness	Authority	Hub
Media	16	162	0.714	0.227
Social networks	14	131	0.630	0.201
Aquaculture average	1.3	2.86	0.061	0.191

Source: Own elaboration.

4.2. Relationship between organizational, productive, and social network variables

Table 7 presents a description of the aquaculture groups' production variable and the COVID-19 knowledge networks. In Table 8, it is shown that the producers linked with the knowledge networks in the Health sector, Private sources, and Media reduced their production during the confinement period (April–August 2020) compared to the pre-COVID-19 period. However, the network most affected was the Private one, with the largest drop in production compared to other networks. On the other hand, the farms that slightly increased their production during confinement were those in the government network.

Regarding the remaining variables (Productive Impact, Increase in Safety Measures, and Mitigation Plan), there is a similarity across all knowledge networks. However, the Private network stands out, as despite experiencing a considerable decline in productivity, only 57% of the aquaculture groups within this network reported having a backup plan to face a prolonged outbreak. This could indicate

Table 7. Descriptive statistics of the productive variable in relation to COVID-19

Variables	Health Network	Private Network	Government Network	Media Network
Network Variables				
Betweenness	122 (155.9)	630	.8 (.273)	146.5 (21.9)
Maximum Authority	.981	.986	.5	.714
Maximum Hub	.188	.164	.5	.227
Productive Variables				
Production before COVID-19 (Kgs)	59,805 (71,745)	92,040.17 (117,339.39)	64,243.75 (77,780.90)	74,413.63 (71,833.51)
Production during COVID-19 (Kgs)	53,171.09 (54,189.83)	84,789.14 (105,891.85)	64,510.12 (70,437.55)	71,095.21 (68,401.77)
COVID-19 affected production =1	.80 (.40)	.71 (.45)	.87 (.35)	.72 (.45)
Increased biosecurity measures since COVID-19 =1	.82 (.38)	.85 (.35)	.62 (.51)	.72 (.45)
Has plan for extended outbreak=1	.77 (.42)	.57 (.50)	.75 (.46)	.59 (.50)

Source: Own elaboration
Note: Table shows the mean of each variable and the standard deviation in parentheses.

that the private network, despite its levels of intermediation, authority, and hub status, did not provide sufficient knowledge to the farms connected to it to sustain production during the COVID-19 lockdown period.

5. Conclusions

Globally, Mexico ranks seventh in food production from the agricultural sector. In the fishing and aquaculture field, it has the potential to expand the national food supply, contribute to food security, generate foreign exchange through exports, and serve as a source of direct and indirect employment, thereby contributing to the region's social well-being.

The objective of this study was to analyze the knowledge transfer networks related to COVID-19 among shrimp-producing aquaculture groups in the northern Pacific region of Mexico, with a special focus on the state of Sinaloa, and to understand how these networks contributed to mitigating the effects of COVID-19 at the organizational and productive levels.

Collective efforts among aquaculture farmers and the capacity to manage knowledge through business networks or interconnectivity among the different entities that provide information—as well as the producers of scientific-technological knowledge who strengthen cooperation ties to transmit resources to society—substantially contribute to the competitive performance of companies and help mitigate the turbulent impacts produced by the market.

This research provides an empirical contribution to the literature on the COVID-19 pandemic within the agricultural system, especially in aquatic sectors such as Pacific white shrimp aquaculture. Furthermore, it allows researchers and producers to understand the structure of networks and knowledge flows for the benefit of aquaculture farmers and companies.

Based on the results, it is reported that through Social Network Analysis (SNA), there are different sources of information that aquaculture farmers turn to in order to acquire knowledge about COVID-19 and its effects on shrimp farming. This information enabled a comparative analysis of the different knowledge transfer networks present in the northern Pacific region of the state of Sinaloa.

Through SNA, four networks were identified as knowledge transfer channels (health sector, private sources, government sector, and media), which producers use to obtain information about COVID-19 and its impact on the studied agricultural activity. One of the main limitations of the study lies in the sample size, which limits the ability to generalize the large-scale impact. However, specific data can still be retrieved for the aquaculture groups in the state of Sinaloa. Originality. This study provides an analysis of the topology of COVID-19 knowledge networks for an aquaculture sector that has been little studied to date.

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